Ford

Ford Motor Company

3001 Miller Road
Dearborn, Michigan 48121

October 10, 1985

Attention: 5HS-13
RCRA Activities
US EPA Region V
P. O. Box 3587
Chicago, Illinois 60690-3587

SUBJECT: Ford Allen Park Clay Mine
Groundwater Monitor Waiver - 40 CFR 265.90 (c)
MID 980568711

Gentlemen:

The facility groundwater waiver demonstration was provided to your Technical, Permits and Compliance Section on January 26, 1983.

Subsequent studies completed since that time have been provided for your review in the form of a revised demonstration dated October 7, 1985.

As requested at the October 9, 1985 meeting, we provide herewith a revised introductory page of the subject groundwater waiver demonstration dated October 10, 1985. Please replace the October 7, 1985 introductory page with the enclosed revision.

Very truly yours,

Ben C. Trethewey

Ben C. Trethewey, Manager
Mining Properties Department

DSM/lr

Enclosures

COPY 2

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October 10, 1985

Ford Motor Company

Allen Park Clay Mine Landfill

E.P.A. I.D. No. MID 980568711

Exhibits A-I attached

Demonstration for Exemption of Subpart F Requirements
Under 40 CFR 264.90 (b) (4) and 40 CFR 265.90 (c)

Demonstration is hereby made to waive certain groundwater monitoring requirements as provided for under 40 CFR 264.90 (b) (4) and 40 CFR 265.90 (c) of the RCRA rules, based on the favorable site geology to the aforementioned rules. Specifically, the requested exemption includes all sampling of the artesian aquifer immediately below the insitu saturated clay liner.

Site Description

Depositional Environment:

The site hydrology is governed by the last glacial period in which the Huron-Erie ice lobe occupied southeast Michigan as shown on Exhibit A. When the ice lobe retreated, a proglacial lake (Lake Maumee) formed, as shown on Exhibits B and C. The site vicinity is located at least 16 miles from the shores of this lake. The clay sediments deposited in the site vicinity reflect this low energy depositional environment. The lacustrine clay is generally 80-120 feet in thickness and has become an effective aquiclude since the recession of the lake. The recharge area for the underlying aquifer is the moraine and outwash complex to the northwest and the underlying Devonian carbonate formations. There are no groundwater withdrawal wells within a three mile radius of the facility.

Artesian Aquifer:

The confined aquifer is located approximately 70 feet below the existing grade at the Allen Park site and varies in thickness from one to six feet. It exerts an upward hydrostatic pressure on the clay aquiclude equivalent to 80 feet of head. This hydraulic gradient in the upward direction is a counteracting force against those of leachate migration (drag coupling effect and chemico-osmotic diffusion). Under these conditions, there is no potential for migration of liquid from the regulated unit to the uppermost aquifer during the active life of the regulated unit and the post-closure care period. Refer to Exhibit D for a full discussion on leachate migration at the facility.

Subsurface Soil Conditions:

The uniformity of the clay sediments in the Detroit area (Erie-St. Clair Plain) has been documented by the numerous soils exploration and foundation engineering studies required for all of the building and construction projects in the vicinity.

To be site specific, the following documentation has been established:

1) Clay mining operations, excavating clay for the manufacture of cement, have encountered more than 45 feet of uniform material over the entire site.

2) Seismic work on the cell bottom indicates that the bedrock is between 57 and 70 feet below the cell bottom with uniform material to that depth. Refer to Exhibit E.

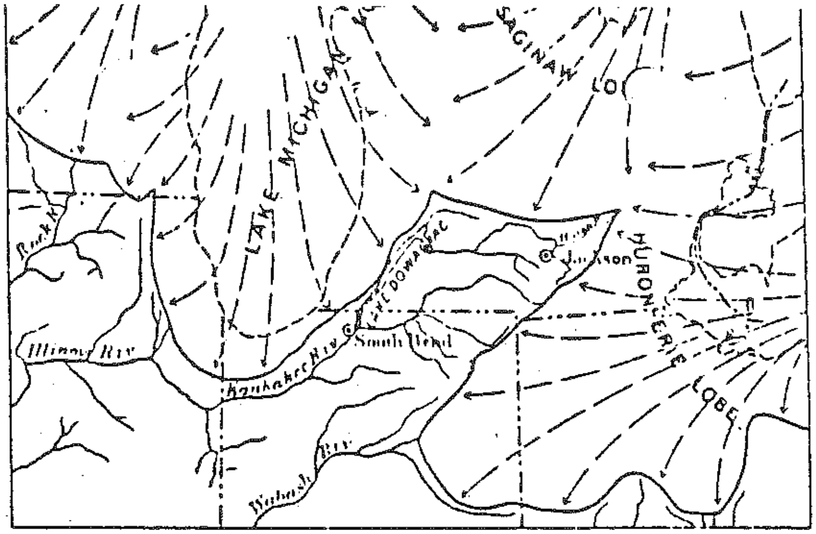

EXHIBIT A (Map from Frank Leverett)

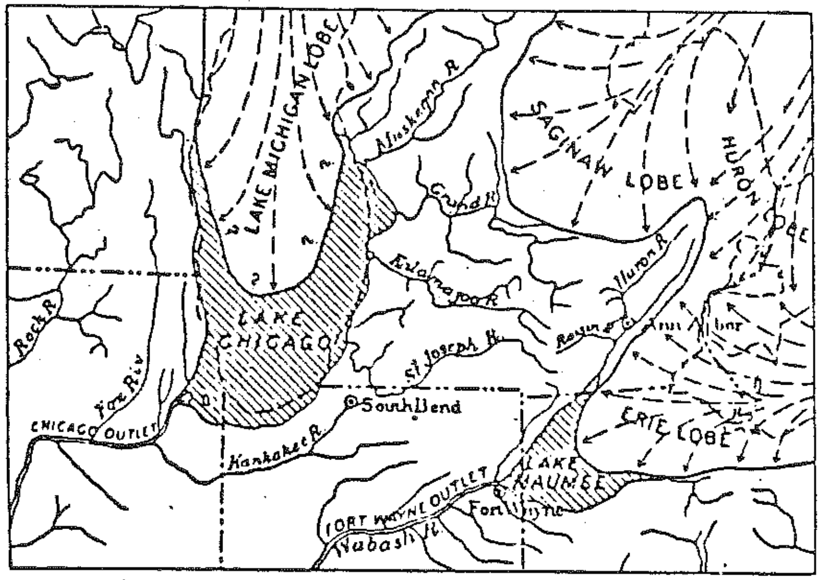

EXHIBIT B (Map from Frank Leverett)

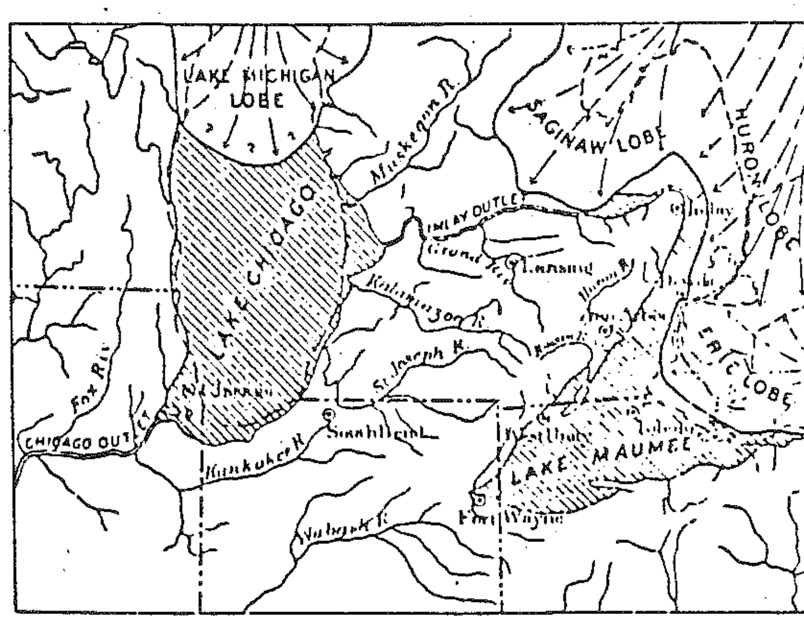

EXHIBIT C (Map from Frank Leverett)

Exhibit D

Report Prepared for:

Wayne Disposal, Inc.

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

by

Donald H. Gray
Professor of Civil Engineering
The University of Michigan

Ann Arbor, Michigan

July 1983

SUMMARY

The possibility of leachate migration downward from the Allen Park Clay Mine/Landfill and contamination of an aquifer beneath were evaluated.

Analyses show that density differences between the leachate and groundwater will not cause a downward migration nor will they lead to a diffusion efflux from the site. A thick, uniform layer of silty clay beneath the site coupled with an upward hydraulic gradient effectively precludes the latter.

Comparison with results of salt water intrusion studies across clay aquitards having similar properties as the clay beneath the Allen Park site show that the solute (salt) will take at least 800 years to migrate across a clay barrier 30 feet thick under chemico-osmotic diffusion alone. A counter (or upward) hydraulic gradient will lengthen this breakthrough time even further.

There are insufficient amounts of organic compounds in the waste to affect the permeability of the clay. The probability of accelerated leachate migration through the underlying clay is not supported by the composition of the wastes and the nature of the clay nor by the findings of leachate permeability studies reported in the technical literature.

Under these circumstances any observed increases in contaminant levels of monitor wells in the aquifer underlying the site could more reasonably come from sources laterally upgradient from the site rather than the clay mine/landfill above the site.

TABLE OF CONTENTS

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

I. INTRODUCTION

The Ford Motor Company who operate the Allen Park Clay Mine/Landfill have recently petitioned to discontinue ground water monitoring of an aquifer located approximately 70 feet below existing grade at the site. The landfill is underlain by dense, lacustrine clay which behaves as an aquiclude or aquitard. At least 25 feet or more of residual clay thickness separates the bottom of the landfill from the underlying aquifer. The aquifer is under artesian pressure and exerts an upward hydrostatic pressure on the base of the clay aquitard equivalent to 80 feet of head. A general cross section or profile illustating these soil and hydrologic conditions at the site is shown in Figure 1.

Applicant maintains in his petition for discontinuance (EPA I.D. No. MIT 980568711) that monitoring is not necessary at the site because of a) the dense, uniform clay underlying the site which has a hydraulic permeability no greater than 6×10^{-8} cm/sec and b) the artesian pressure in the underlying aquifer which results in an upward hydraulic gradient across the overlying clay aquitard. Applicant claims that these site conditions will preclude the possibility of leachate migrating downwards out of the landfill and eventually contaminating the aquifer.

In response to this petition, the Wayne County Department of Public Health has raised several questions and concerns (letter form R.N. Ratz, Public Health Engineer, to B. Trethewey, Mining Properties Department, Ford Motor Company, 28 April 1983). The following concerns were raised in the letter:

1. The petition/report fails to address the possibility of leachate migrating down due to differences in densities of the leachate and groundwater.

2. The petition/report does not indicate if there are any organic constituents in the leachate that may increase the clay's permeability and permit downward movement.

The purpose of the present report is to respond to the above stated concerns. Additional information about the geohydrology of the site, about past containment/migration studies, and about the likely nature of the leachate and its effect on clay permeability are evaluated herein to determine the danger of landfill leachate migrating downwards from the site and reaching the underlying aquifer.

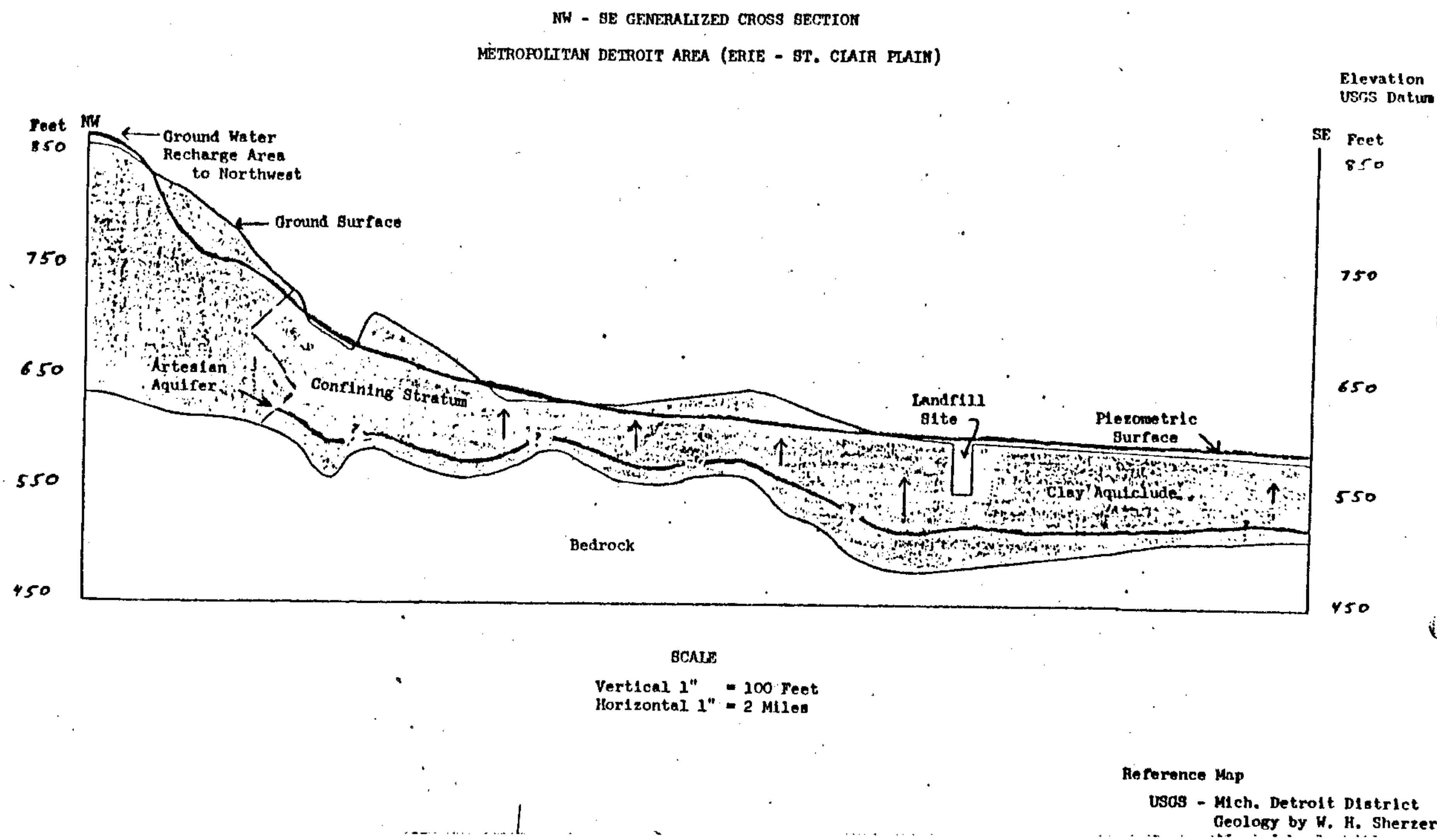

Figure 1. Generalized cross-section through Allen Park Clay Mine/Landfill showing soil and hydrologic conditions.

II. THE INFLUENCE OF PERMEANT DENSITY ON LEACHATE MIGRATION ACROSS CLAY BARRIERS

A. GENERAL

Permeant density plays a direct and indirect role in flow phenomena in porous media. Permeant density can affect solvent or solution flow rates via its influence on hydraulic conductivity. This influence can be calculated and shown to be minor or insignificant compared to the more likely and important influence of permeant density on solute diffusion.

A newly introduced permeant with a high concentration of dissolved material (e.g., a leachate) will also have a higher density. This high concentration in turn will cause the solute to diffuse through a porous medium to regions of lower concentration. It is this manifestation or aspect of a density increase in the permeant that requires careful scrutiny and analysis. In other words, the role and influence of permeant density are more important to solute diffusion under concentration gradients as opposed to solvent (or solution) convection under hydraulic gradients.

The analyses that follow are offered in support of these claims.

B. INFLUENCE OF PERMEANT DENSITY INCREASE ON HYDRAULIC PERMEABILITY

Both the viscosity and unit weight of a permeant can influence the permeability of a soil to a particular permeant. The hydraulic conductivity is defined in this case as a flow velocity under a unit hydraulic gradient (the usual practice in civil engineering). The influence of permeant density and viscosity can be ascertained explicitly by defining another permeability, i.e., the "intrinsic" or "absolute" permeability

$$K = \frac{k\,\mu}{\gamma} \qquad (1)$$

where:
- k = hydraulic conductivity, cm/sec
- K = intrinsic or absolute permeability, cm^2
- γ = permeant density or unit weight, $dynes/cm^3$
- μ = permeant viscosity, poise

The intrinsic permeability(K) is a property only of the solids or matrix through which the permeant passes. Accordingly, for a particular soil (i.e., given grain size distribution and soil structure) and in the absence of permeant-soil reactions, K should be a constant. The influence of a variation in viscosity and density of the permeant on the hydraulic conductivity can be determined from this fact and from a relationship derived from Equation 1, viz.,

$$k_2 = k_1 (\gamma_2/\gamma_1) (\mu_1/\mu_2) \qquad (2)$$

where: subscript 1 - initial conditions (grnd water)
subscript 2 - final conditions (leachate)

An increase in density of the permeant will apparently cause a higher permeability. But, this same increase in density can also result in an increase in viscosity which will reduce the permeability. Both influences together will tend to offset one another, and it is unlikely that a density increase in the permeant (leachate) will significantly affect hydraulic conductivity. Furthermore, even if viscous retardation is discounted, density increases are highly unlikely to significantly increase permeability in actual practice as the following example will show.

Assume the ground above an aquitard or clay barrier is flooded with a fairly concentrated brine solution, namely sea water. The density of sea water (with a TDS of 36,000 ppm) is 1.036 gm/cc at 4° C vs. the density of the present interstitial water (with an average TDS of 1550 ppm) which is 1.002 gm/cc. This leads to a density ratio of 1.034 which is equivalent to only a 3.4 per cent increase in hydraulic conductivity (discounting viscous retardation). Therefore, density has little effect on hydraulic conductivity despite the almost 20 fold increase in dissolved solids concentration. It is the influence of the latter change, i.e., the increase in dissolved solids concentration, that requires careful analysis in evaluating the effectiveness of a clay barrier in containing leachate migration in this case.

C. INFLUENCE OF PERMEANT DENSITY INCREASE ON SOLUTE DIFFUSION

1. Background

Dissolved solids or solutes in a permeant can be transported through soils under both hydraulic and concentration gradients. The former is referred to as "drag coupling" and the latter as "chemico-osmotic diffusion." Both types of movement should be considered when evaluating the effectiveness of a clay barrier for preventing leachate migration.

Chemico-osmotic effects in fine grained soils have been examined in some detail by Olsen (1969) and Mitchell et al. (1973). The importance of chemico-osmotic diffusion increases in fine grained soils wilth low hydraulic conductivities. Studies commissioned by the State of California (1971) on salt intrusion problems in aquifer-aquitard systems have shown that as aquitards become clay rich and their permeabilities fall to levels on the order of .002 gpd/ft^2 or 10^{-7} cm/sec, the migration of solutes will be controlled by chemico-osmotic diffusion.

2. Flow of Solute under Combined Hydr. and Chem. Gradients

Equations can be derived which describe the flows of solute and solution in the pores of a sediment. The derivation of these equations and assumptions on which they are based are given by Mitchell et al.(1973). The one-dimensional, vertical, steady state flux of solute across a clay aquitard under a combined salt concentration(chemical) gradient and hydraulic gradient is given by the following relationship:

$$J_s = [(\gamma_w/TR)c_s k_{ch} + c_s k_h]\,\partial h/\partial z + [\,D + c_s k_{ch}]\,\partial c_s/\partial z \quad (3)$$

where: J_s = salt flux across an aquitard, moles/sec/cm^2
$\partial h/\partial z$ = hydraulic gradient (dimensionless)
$\partial c_s/\partial z$ = solute concentration gradient, moles/cm^4
D = diffusion constant, cm^2/sec
R = gas constant, ergs/mole/°K
γ_w = density of water, dynes/cc
T = absolute temperature, °K
c_s = average salt concentration, moles/cc
k_h = hydraulic conductivity, cm/sec
k_{ch} = chemico-osmotic coupling coefficient, cm^5/mole/sec

Relative contributions to the salt or solute flux can be calculated from Equation 3. Movement of solute can occur by diffusion whether a hydraulic gradient is present or not. A superposed hydraulic gradient may retard or accelerate movement of solute depending on:

a) Relative magnitude and direction of the hydraulic and solute concentration gradients.

b) Values of the hydraulic conductivity and chemico-osmotic coupling coefficient.

Equation 3 only yields the steady state flux of solute under combined hydraulic and chemical gradients. Equations can also be derived that give the initial or time dependent solute fluxes and the time required for "breakthrough" or first appearance of increased solute concentration on the downstream side of the aquitard. This initial, non-steady state process is quite complicated. Examples have been worked out for aquitards of different thicknesses and composition by Mitchell et al.(1973).

One of the most important findings of these studies on salt flux across clay aquitards was the importance of aquitard thickness on breakthrough time. Because the initial movement is non-steady, the breakthrough time increases with the square of the thickness of the aquitard. Theoretical studies of salt water intrusion across aquitards (State of California, 1971) have shown that salt ions will

take up to 800 years to migrate across an aquitard 30 feet thick under chemico-osmotic diffusion alone. If the thickness is reduced to 10 feet, the breakthrough time decreases to only 80 years. The presence of an hydraulic gradient could either accelerate or retard this time depending on the relative magnitude and direction of this gradient and other factors cited previously (see Figure 3).

3. Likelihood of Solute Efflux Through Clay at Allen Park Site

Solutes will tend to migrate or diffuse downward from the landfill along a concentration gradient. On the other hand, this movement can be impeded or even arrested by the upward hydraulic gradient as a result of artesian pressure in the underlying aquifer. Static water levels in monitor wells around the landfill show that the piezometric surface is almost 10 feet above existing grade or ground surface elevation at the site (see Table 1). The net, steady state flux of solute, if any, can be determined under these conditions from the solute flow equation cited previously (Equation 3).

It is also pertinent to examine the results of a similar type of study commissioned by the State of California (1971). The latter study was designed to determine salt efflux rates and breakthrough times in an aquitard-aquifer system in the coastal ground water basin near Oxnard, California (see Figure 2). The problem posed in the California study was basically the same as the present one; namely, given a sudden increase in dissolved solids or solute concentration atop a clay barrier (or aquitard) how long before the salt migrated downward and reached an underlying aquifer and at what rates of efflux? The problem was compounded in the California example as a result of drawdown of the piezometric surface in the underlying aquifer which also caused a downward hydraulic gradient.

The two aquitards are quite similar in their important respects. Both are approximately the same thickness, have the same initial dissolved solids concentration, and are composed of clayey sediments with low hydraulic conductivities. The salient charateristics and parameters of these two aquitards are summarized and compared in Table 2. The main difference appears to be in their respective hydraulic conductivities-- the Allen Park clay is an order-of-magnitude lower.

A dissolved solids concentration equal to that of sea water was assumed in the leachate overlying the Allen Park clay. Sea water is a good "worst case" choice because sodium ions have high diffusion mobilities and are not preferentially adsorbed on clay exchange sites as heavy

TABLE 1. ALLEN PARK CLAY MINE

MONITOR WELL - WATER LEVEL READINGS

Well Number	Ground Elevation, Ft.	Well Elevation[1] USGS	Ground Water[2] Elevation 11-4-81	Δ	Ground Water[3] Elevation 5-29-81	Ground Water[3] Elevation 3-26-81
2	595.1	600.76	600.67	5.6	600.44	600.21
5	595.7	605.92	605.09	9.4	604.62	604.49
7	594.1	597.35	591.01	-3.1	593.23	594.14
10	593.4	603.03	601.81	8.4	601.93	601.56
W-101	593.9	601.47	601.21	7.3		
W-102	591.3	600.81	603.22[4]	11.9		
W-103	593.9	605.06	603.52	9.6		
W-104	594.1	603.82	603.81	9.6		
W-105	594.5	604.08	603.86	9.4		

$\Delta_{AV} = 8.9$

(1) Well Elevation is recorded as top of standpipe.

(2) Data Recorded by Michigan Testing Engineers, Inc.

(3) Data obtained from Michigan Department of Natural Resources.

(4) Well extended temporarily to obtain water level.

TABLE 1

MICHIGAN TESTING ENGINEERS INC.

TABLE 2. COMPARISON OF AQUITARD PROPERTIES AND SITE PARAMETERS

AQUITARD PROPERTY OR SITE PARAMETER	OXNARD CALIFORNIA	ALLEN PARK MICHIGAN
Composition	clayey silt & silty clays	silty clay
Thickness, ft	30	25 - 35
Ave. Water Content, %	24	20
Ave. Liquid Limit, %	31	28
Ave. Hydraulic Conduct, cm/sec	1×10^{-7}	2.6×10^{-8}
Hydraulic Gradient	0.33 - 1.0 (downward)	2.7 (upward)
Initial (interstitial) Pore Water Solute Conc, ppm	1800	1550
Final Solute Conc, ppm	36,000	36,000 (assumed)
Chemico-Osmotic Coupling Coefficient, cm^5/mole/sec	6.2×10^{-4}	6.2×10^{-4}

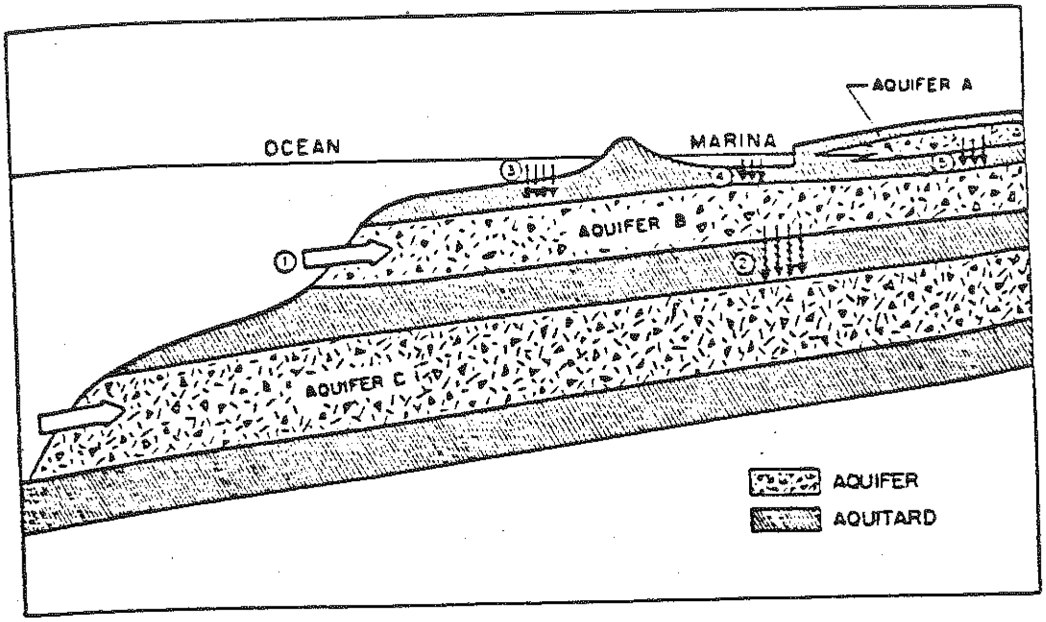

Figure 2. Generalized cross-section of multiple aquifer in a coastal basin. Salt flux across aquitard can occur as result of either salt water intrusion into aquifer (1,2) or salt water entering directly above aquitard in shallow coastal waters or marinas (3,4), or from salt contamination in near surface, perched aquifer (5).

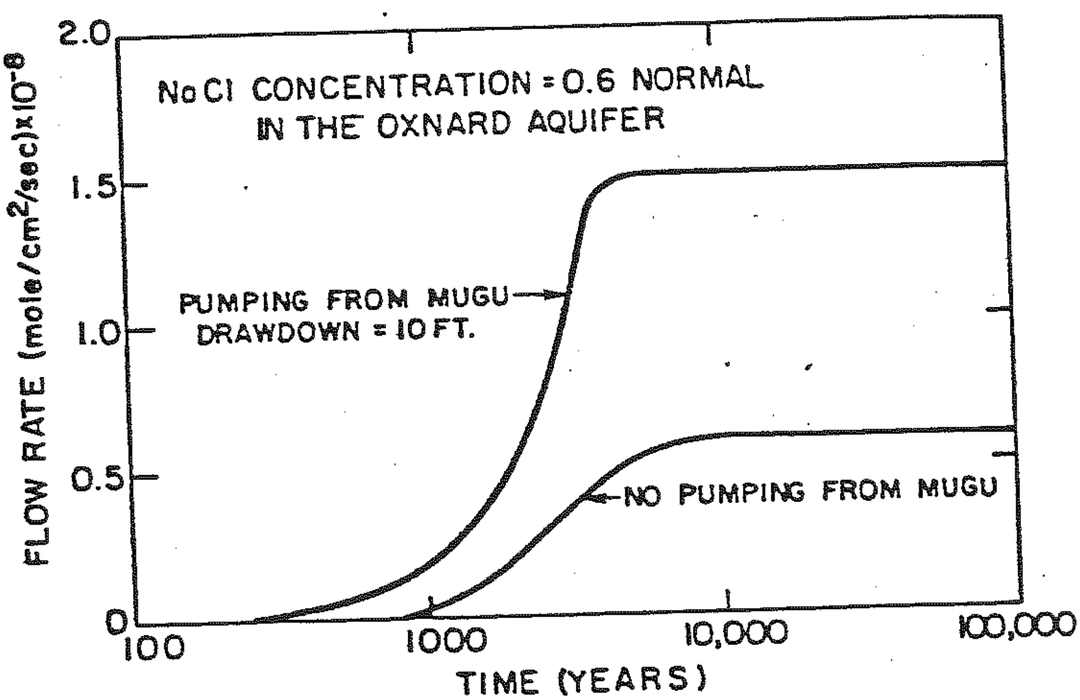

Figure 3. Solute efflux across aquitard into underlying aquifer as a result of salt water intrusion in overlying aquifer. Aquitard is 30 feet thick and has a hydraulic conductivity of 10^{-7} cm/sec. Pumping from lower (Mugu) aquifer superposes a 0.33 downward gradient on system.

metal ions would tend to be. The same chemico-osmotic coupling coefficient used in the California aquitard was also assumed applicable for the Allen Park clay. The value used is reasonable for the type of clay sediments present.

Results of the California study are presented in Figure 3 which shows the salt influx into the underlying aquifer as a function of time. Curves are presented for a no drawdown and 10-foot drawdown case (assuming the hydraulic gradient acts in the same direction as the salt concentration gradient). The horizontal portion of the two curves represents the steady state salt flux.

The main things to notice from this figure are the large breakthrough time (800 years) for the "no drawdown" case (i.e., in the absence of any hydraulic gradients) and the fact that in this aquitard the salt flux caused by drag coupling under a hydraulic gradient is larger. The steady state salt flux from the drag coupling under a combined 10-foot drawdown and salt concentration gradient is almost three times that from diffusion alone (no drawdown). Hence, in the event the hydraulic gradient was reversed, there would be no breakthrough and no downward salt flux provided the upward gradient exceeded about 0.2. In other words, under these conditions the two salt fluxes would be mutally opposed and exactly counterbalanced.

The relative contributions to steady state efflux in this example can be calculated with the aid of Equation 3. The following parameter values (taken from the study) were used in the calculation:

$$\partial h / \partial z \approx \Delta h / \Delta L = 10/30 = 0.33$$

$$\partial c / \partial z \approx (c_{s_2} - c_{s_1}) / \Delta L = \frac{0.57 \times 10}{914} = 0.62 \times 10 \text{ moles/cm}^4$$

$$c_s = (c_{s_2} + c_{s_1}) / 2 = \frac{(0.60 - 0.03) \times 10}{2} = 0.32 \times 10 \text{ moles/cm}^3$$

$$D = 10^{-5} \text{ cm}^2/\text{sec}$$

$$R = 8.32 \times 10^7 \text{ ergs/mole/}^\circ\text{K}$$

$$T = 300\ ^\circ\text{K}$$

$$\gamma_w = 10^3 \text{ dynes/cc}$$

$$k_h = 10^{-7} \text{ cm/sec}$$

$$k_{ch} = 6.2 \times 10^{-4} \text{ cm}^5/\text{mole/sec}$$

Using these values the calculated contributions to steady state solute flux are respectively:

Drag Coupling: $J_{s_1} = [(\gamma_w/RT)c_s k_{ch} + c_s k_h] \partial h/\partial z$

$$= \left[\frac{10^3(2\times10^{-7})}{8.32\times10^7(.3\times10^{-3})} + 0.32\times10^{-3}(10^{-7})\right] 0.33$$

$$= 1.056 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{0.98 \times 10^{-8} \text{ moles/sec/ft}^2}$$

Chemico-Osmotic Diffusion:

$$J_{s_2} = [D + c_s k_{ch}] \partial c_s/\partial z$$

$$= [10^{-5} + 2\times10^{-7}] \ 0.62\times10^{-6}$$

$$= 0.63 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{0.58 \times 10^{-8} \text{ moles/sec/ft}^2}$$

The total salt flux is the sum of the contributions from drag coupling and chemico-osmotic diffusion or

$$J_s = J_{s_1} + J_{s_2}$$

$$= (0.98 + 0.58) \times10^{-8}$$

$$= \underline{1.56 \times 10^{-8} \text{ moles/sec/ft}^2}$$

These calculations are in agreement with the results shown in Figure 3 for steady state salt inflow under combined gradients. They also illustrate that the drag coupling contribution under a 10-foot drawdown (0.33 hydraulic gradient) exceeds the chemico-osmotic diffusion contribution.

In the case of the clay aquitard beneath the landfill at Allen Park, the average hydraulic conductivity is almost an order-of-magnitude lower (2.6×10^{-8} vs. 10^{-7} cm/sec). This will tend to decrease the drag coupling. On the other hand, this tendency will be more than offset by higher hydraulic gradients at this site. If the level of the leachate is kept at or close to the bottom of the landfill, then the gradient will approach 80/30 or 2.7. The drag coupling component of solute flux in this case will be

$$J_{s_1} = \left[\frac{10^3(2\times10^{-7})}{8.32\times10^7(.3\times10^{-3})} + 0.32\times10^{-3}(2.6\times10^{-8})\right] \times 2.7$$

$$= [0.008\times10^{-12} + 0.832\times10^{-11}] \times 2.7$$

$$= 2.25 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{2.09 \times 10^{-8} \text{ moles/sec/ft}}$$

This flux is greater than 3X the chemico-osmotic flux; and since it acts in the opposite direction, there will be no net downward flux of solute at the Allen Park site. The critical hydraulic gradient to maintain a zero net salt efflux is 0.8. This means that the groundwater table could rise to within 12 feet of present ground elevation (~595 ft) in the landfill and there would still be a sufficient upward hydraulic gradient (drag coupling effect) to completely counter solute efflux under chemico-osmotic diffusion (see summary below).

Position of Ground Water Table in the Landfill	Upward Hydraulic Gradient	Net, Steady State Solute Efflux Rate (moles/sec/ft^2)
At bottom	2.7	-1.51×10^{-8} (net influx)
12 feet from top	0.8	zero
At top	0.33	$+0.32 \times 10^{-8}$

These calculations are based on the existence of a static or piezometric head in the underlying aquifer approximately 9-10 feet above ground elevation (see Table 1).

Assumption of worst case conditions, namely, a rise in the groundwater table in the landfill to ground surface elevation, leads to a small, steady state efflux rate from chemico-osmotic diffusion. This occurs because the resulting hydraulic gradient (0.33) is no longer large enough to completely oppose the chemico-osmotic salt flux. The breakthrough times, however, would be so immense (1000's of years) that the steady state flux under these conditions is largely irrelevant.

It is important to note that the preceding calculations are also based on the following "worst case" assumptions:

1. A highly saline leachate with a concentration and composition equal to that of sea water.

2. No interaction between the solute and clay.

In actual practice, there would be some uptake and adsorption of solutes on the clay. This adsorption would attenuate or limit further solute concentrations in the leachate as it passed through the clay.

III. EFFECT OF LEACHATE CONSTITUENTS ON THE PERMEABILITY OF CLAY

A. GENERAL BACKGROUND

The possibility that leachate--either in the solvent or solute phase--might affect clay permeability and hence its containment integrity has been raised by a number of investigators (Anderson and Brown, 1981; Haxo, 1981; and Folkes, 1982). One of these studies has shown that concentrated organic liquids can increase clay permeability by several orders-of-magnitude (Anderson and Brown, 1981).

All of these studies were conducted in the laboratory with simulated leachates from particular types of wastes and under particular testing conditions. The danger of blindly applying these test results to a field situation have been noted recently by Gray and Stoll (1983). It is essential to ask the following before the results of these lab tests can be applied to a given field situation:

1. What was the nature of the leachate in the lab tests? What are the concentrations of various constituents in the leachate in the field as opposed to the lab tests? How relevant are the lab test results in the light of potentially large differences in leachate composition (lab vs. field)?

2. How did the leachate contact or interact with the clay in the lab tests? Was it forced through? If so, at what gradient? Is there any prospect that the leachate will be able to penetrate/permeate through the clay containment in the field in like manner? In other words are the necessary gradients and other conditions present to permit this to happen?

3. What was the failure or clay degradation process by which the apparent permeability increase occured in the lab tests? Was it by a) dissolution, b) syneresis, c) piping? Could these mechanisms reasonably occur in the field given the type, water content, and density of the in-situ clay plus the nature and concentration of organic and inorganic compounds in the leachate?

B. WASTE AND LEACHATE COMPOSITION AT THE ALLEN PARK CLAY MINE

The types, composition, and relative amounts of wastes placed in the Type II Solid Waste Landfill at Allen Park are shown in Tables 3 and 4. The results of typical E.P.T leachate tests on these wastes are shown in Table 5. The likely nature and composition of the landfill leachate can be estimated from this information. This estimate is adequate for purposes of evaluating the probable effect of the leachate on clay permeability.

TABLE 3. ALLEN PARK CLAY MINE - SOLID WASTE LANDFILL CONSTITUENTS

Fly Ash	-	50%
Blast Furnace Filter Cake	-	15%
Construction Debris - Sweepings - Clean-Up	-	14%
BOF Dust	-	6%
Foundry Sand	-	6%
Electric Furnace Dust	-	4.8%
Coal and Coke	-	3%
Coke Oven Decanter Tar Sludge	-	0.6%
Glass	-	0.5%
Wood Ash	-	0.5%
BOF Kish	-	0.3%
Wastewater Treatment Sludge	-	0.2%
Grinding Mud	-	0.1%

TABLE 4. ALLEN PARK CLAY MINE WASTES. TYPICAL AS RECEIVED ANALYSES (mg/kgm).

	Decanter Tank Tar Sludge	Electric Arc Furn. Dust	Blast Furn. Flue Dust	BOF Flue Dust	Blast Furn. Filter Cake	Foundry Sand	BOF Kish	Fly Ash	Lime Dust	Coke Breeze
EP Toxic	No	Yes(Zn,Pb,Cd)	No	No	No	No	No	Exempt	No	No
Iron	----	350,000	122,000	560,000	150,000	1,200	490,000	34,500	----	5,000
Carbon	----	4,700	520,000	7,400	404,000	6,600	240,000	194,000	----	950,000
Arsenic	----	50	19	42	2	20	70	----	----	15
Barium	----	<1	<1	<1	20	<1	<1	----	----	<1
Cadmium	----	95	<1	50	8	<1	<1	----	----	<1
Chromium	----	500	<1	130	70	<1	60	----	----	1
Lead	----	<4,500	<1	3,000	350	44	<1	----	----	69
Mercury	----	<1	<1	<1	<1	<1	<1	----	----	<1
Selenium	----	120	98	<1	<1	35	70	----	----	3
Silver	----	6	<1	<1	9	<1	<1	----	----	19
Manganese	----	39,000	7,500	10,000	4,500	79	2,000	----	----	70
Zinc	----	150,000	120	22,000	400	40	194	----	----	110
Phosphorus	----	450	200	190	300	400	170	----	----	90
Sulfur	----	3,600	4,000	1,600	4,000	200	850	3,100	----	7,300
Calcium	----	61,000	18,000	2,000	20,000	60	580	13,100	714,700	390
Magnesium	----	11,000	7,500	9,600	13,000	100	3,000	5,400	----	300
Aluminum	----	2,400	2,200	<2	3,700	<2	1,600	147,200	----	<2
Silicon	----	15,000	20,000	8,000	83,000	450,000	25,000	201,700	----	20,000
Potassium	----	5,900	980	5,000	2,200	170	640	9,700	----	220
Sodium	----	5,200	440	2,300	1,500	390	630	3,700	----	650
Fluorine	----	26	10	23	4	<1	48	----	----	<1
Cyanide	14	<1	<1	<1	3	<1	<1	----	----	2
Phenol	1,800	<1	<1	<1	3	<1	2	----	----	3
Naphthalene	2,700	----	----	----	----	----	----	----	----	----

TABLE 5. ALLEN PARK CLAY MINE SOLID WASTES TYPICAL E.P.T. LEACHATE TEST RESULTS (Mg/1)

Parameter	Blast Furnace Flue Dust	BOF Flue Dust	Blast Furnace Filter Cake	Foundry Sand	BOF Kish	Coke Breeze	Wastewater Treatment Sludge
Arsenic	0.04	0.02	$<$ 0.1	0.03	0.1	$<$0.1	.008
Barium	$<$0.8	$<$0.04	$<$ 0.8	$<$0.08	$<$ 0.8	$<$0.8	.45
Cadmium	0.01	0.03	$<$ 0.08	$<$0.005	$<$0.005	$<$0.005	.005
Chromium	$<$ 0.1	$<$ 0.05	$<$ 0.05	$<$0.1	$<$ 0.1	$<$0.1	.101
Lead	$<$ 0.2	1.7	1.7	$<$ 0.2	$<$0.2	$<$0.2	.025
Mercury	0.0007	$<$ 0.01	$<$ 0.2	$<$0.2	$<$0.2	$<$ 0.2	.0005
Selenium	1.0	$<$ 0.01	$<$ 0.2	0.10	0.4	$<$0.5	.008
Silver	$<$ 0.1	$<$ 0.01	$<$ 0.01	$<$0.1	$<$ 0.1	$<$ 0.1	.006

Compiled By [illegible]
March [illegible], 19[illegible]

The data in Tables 3 and 4 indicate that 50 per cent of the solid waste consists of relatively inert fly ash and that some 89 per cent of the wastes consist of materials that do not contain significant amounts of heavy metals (Zn, Pb, Cd) or organics known or suspected to be toxic such phenol and naphthalene (see Table 4). The coke oven decanter tar sludge is a possible source of organics (phenol and napthalene), but this waste comprises only 0.6 per cent of the total stream in the Type II Solid Waste landfill.

C. PROBABILITY OF ORGANICS IN LEACHATE AFFECTING CLAY PERMEABILITY AT ALLEN PARK SITE

Anderson and Brown (1981) found that several organic liquids, viz., aniline, acetone, ethylene glycol, heptane, and xylene, cause large increases in permeability of four compacted clay soils. Pure organic liquids were used in their study. One of the authors (Anderson, 1982) later emphasized that their results cannot be used to support claims that clay liners permeated by dilute organic liquids may be susceptible to large permeability increases.

Haxo (1981) reported results of up to 52 months of liner exposure to selected industrial wastes. He included several organic wastes, namely, aromatic oil, Oil pond 104, and a pesticide. The results of large permeameter tests on a compacted fine-grained soil and admixed materials are summarized in Table 6. Although a small amount of seepage passed through the compacted, fine-grained soil liner, no permeability increases were reported with any of the organic wastes.

On the basis of these studies and with the caveats noted at the beginning of this section in mind, it is possible to evaluate the likely effect of the landfill leachate on clay permeability at the Allen Park site.

1. Type II Solid Waste Landfill

As noted previously the existing landfill contains small quantities of coke oven decanter tar sludge which is a possible source of organics (phenol and naphthalene), but this waste comprises only 0.6 per cent of the total. Phenol and naphthalene are present in the tar component of this waste in concentrations estimated by Desha (1946) of 0.1 and 2.2 per cent by weight respectively. Accordingly, the amount of phenol and naphthalene present in the total waste stream are .006 and .013 per cent by weight respectively. These amounts constitute a very low fraction and they suggest that leachate from the total waste stream will tend to have very low concentrations of phenol and napthalene. Therefore, the organics in the leachate from the Type II Solid Waste landfill are quite unlikely to affect clay permeability.

TABLE 6. EFFECTS OF INDUSTRIAL WASTES ON SOIL AND ADMIX LINERS (from Haxo, 1981)

Liner material	Acidic waste (HNO_3, HF, HOAC)	Alkaline waste (spent caustic)	Lead (low lead gas washing)	Oily waste		Pesticide (weed killer)
				Aromatic oil	Oil pond 104	
Compacted fine-grained soil 305 mm thick	Not tested	Measurable rate of seepage $v_s = 10^{-10}-10^{-9}$ m/s, waste penetrated 3–5 cm after 30 months (*a*)		$k=1.8\times10^{-10}$ $k=2.4\times10^{-10}$ $k=2.6\times10^{-10}$ (tests on soil after 30 months)	†	†
Soil cement 100 mm thick	Not tested	No measurable seepage after 30 months				
Modified bentonite and sand (2 types) 127 mm thick	Not tested	Measurable seepage after 30 months, channelling of waste into bentonite (*b*)			Failed (waste seepage through liner)	‡
Hydraulic asphalt concrete 64 mm thick	Failed	Satisfactory	Waste stains below liner asphalt mushy	Not tested	Not tested	Satisfactory
Spray-on asphalt and fabric 8 mm thick	Not tested	Satisfactory	Waste stains below liner	Not tested	Not tested	Satisfactory

*From data presented by Haxo (1981).
†Same as (*a*).
‡Same as (*b*).

2. Type I Hazardous Waste Landfill

In the future the decanter tar sludge will be placed in a separate landfill that will be upgraded to accept hazardous wastes. This action will increase the relative proportion of organics (phenol and naphthalene) in the waste stream. Leachate tests run on pure samples of decanter tar sludge using a distilled water extraction procedure (Calspan, 1977) have produced phenol concentrations of approximately 500 ppm. Even this concentration is far removed from the very high concentrations of organic solvents used by Anderson and Brown (1981) in their permeability tests on different clays. Accordingly, organics in the leachate from the Type I Hazardous Waste landfill are also unlikely to affect clay permeability.

In summary: It does not appear likely nor reasonable that organics present in the wastes at the Allen Park Clay Mine/Landfill will cause a permeability increase given their low concentration and the absence of any substantiation in the published technical literature for such an increase under these conditions.

IV. CONCLUSIONS

(1). There appears to be very little likelihood of leachate migrating downward from the Allen Park Clay Mine/Landfill and contaminating the aquifer beneath the clay.

(2). A density difference between the leachate and groundwater will have little or no influence on hydraulic permeability or downward migration nor will it lead to diffusion efflux of solutes. A thick, uniform bed of silty clay beneath the site coupled with an upward hydraulic gradient precludes the latter. Calculations and analyses are provided herein to support this finding.

(3). Comparison with results of salt water intrusion studies across clay aquitards having similar properties as the clay beneath the Allen Park Clay Mine site show that the solute (salt) will take at least 800 years to migrate across a clay barrier 30 feet thick under chemico-osmotic gradients alone. A counter (or upward) hydraulic gradient will increase this breakthrough time even more.

(4). The waste and its leachate are unlikely to increase the permeability of the underlying clay. This claim is reasonable in view of the low concentrations of organics in the total waste stream and in the light of the findings and caveats of permeability/exposure tests with organic permeants reported in the technical literature. This conclusion applies to both the existing Type II Solid Waste landfill and a proposed Type I Hazardous Waste landfill that will accept the coke oven decanter tar sludge.

(5). The composition of the waste and underlying clay do not suggest properties or combination of properties that could lead to a containment failure caused by such processes as piping, acid/base dissolution, or syneresis.

(6). Under these circumstances any observed increase in contaminant levels of monitor wells in the aquifer underlying the site could just as well come from other sources laterally upgradient from the site rather than from the clay mine/landfill above the site.

(7). These findings and conclusions support the basis of applicant's petition for discontinuing further monitoring of the wells penetrating the aquifer beneath the site.

JULY 1983 REPORT
CONTAINMENT INTEGRITY OF ALLEN PA[illegible]
CLAY MINE / LANDFILL

1704 Morton Street
Ann Arbor, Michigan
48104

25 September 1983

Mr. Mark Young
Wayne Disposal Company
P.O. Box 5187
Dearborn, MI 48128

RE: Allen Park Clay Mine/Landfill

Dear Mark:

I recently wrote a computer program (*CLAYWALL*) that can be used to calculate solute transport across a clay barrier under combined diffusion and advection (hydraulic flow). The program computes the exit/source concentration ratio (C/Co) as a function of elapsed time (t) on the downstream side of a clay wall or barrier of thickness (X).

The program was written with a clay slurry cut-off wall in mind, but is general enough that it can be used with any clay layer or barrier. The input parameters to the program are:

D_e = efffective diffusion coefficient, ft^2/yr
K = hydraulic permeability, ft/yr
X = thickness of wall or barrier, ft
P = porosity
I = hydraulic gradient...(+) if same direction, (-) if opposite direction to solute concentration gradient
t = elapsed time, yrs

The program is based on the solution to the equation that describes one-dimensional solute transport in a saturated porous medium under both hydraulic and solute concentration gradients. This equation has the following form:

C/Co = 0.5[erfc((X-vt)/sqr(4DK)) + exp(vX/D) erfc((X+vt)/sqr(4DK))]

where: v = ave seepage velocity = (KI/P)

The solution assumes the following conditions:

1. Saturated, one-dimensional flow.

2. No reaction between solutes and porous medium. Chloride typically behaves this way.

V. REFERENCES CITED

Anderson, D. (1982). "Does landfill leachate make clay liners more permeable?" Civil Engineering-ASCE, Vol. 52, #9, 66-69

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Calspan Corp (1977). "Assesment of industrial hazardous waste practices in the metal smelting and refining industry," v. 3, Appendices. EPA Contract No. 68-01-2604, April 1977

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Haxo, H.E. (1981). "Durability of clay liners for hazardous waste disposal facilities," In Landfill Disposal: Hazardous Waste, Proceedings, 7th Annual Research Symposium, U.S. Envl. Protection Agency, Philadelphia, pp. 140-156

Mitchell, J.K., Greenberg, J.A., and Witherspoon, P.A. (1973). "Chemico-osmotic effects in fine-grained soils," ASCE Journ. of SMFD, Vol 91, No. SM4, pp. 307-321

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3. Diffusion controlled, i.e., the pore water velocity is so low that mechanical mixing is negligible and the dispersion is equal to the effective diffusion coeffficient. (this condition is satisfied when $K < 1.0E-07$.

I ran the program using data for the silty clay layer underlying the Allen Park ClayMine/Landfill. The following values for the input data were used:

$D = 0.102\ ft^2/yr\ (6.3E-06\ cm^2/sec)$
(published value for clay tills)
$K = 0.025\ ft/yr\ (2.5E-08\ cm/sec)$
$X = 30\ ft$
$P = 30\ \%$
$I = -0.1, -0.3,$ and -1.0

The results of the analysis are shown in the attached graph. At a counter hydraulic gradient of -0.3 the exit/source solute concentration ratio does not exceed 0.0001 until 700 years have elapsed. You may recall that a counter hydraulic gradient of -0.3 occurs when the leachate is allowed to rise in the landfill to the ground surface...a worst case scenario. For larger (negative) counter hydraulic gradients the ratios become even smaller. In fact for $I < -0.5$ (i.e., counter hydraulic gradients <u>larger</u> than 0.5) the ratio C/Co is less than 1.0E-05 at all elapsed times.

These results confirm the findings of my earlier report which were based largely on analogy to solute transport studies in clay aquitards. The present findings are based on analysis of actual soil and site parameters. Keep in mind, also, that the analysis is still quite conservative because it neglects possible adsorption (reaction) of solutes with the clay.

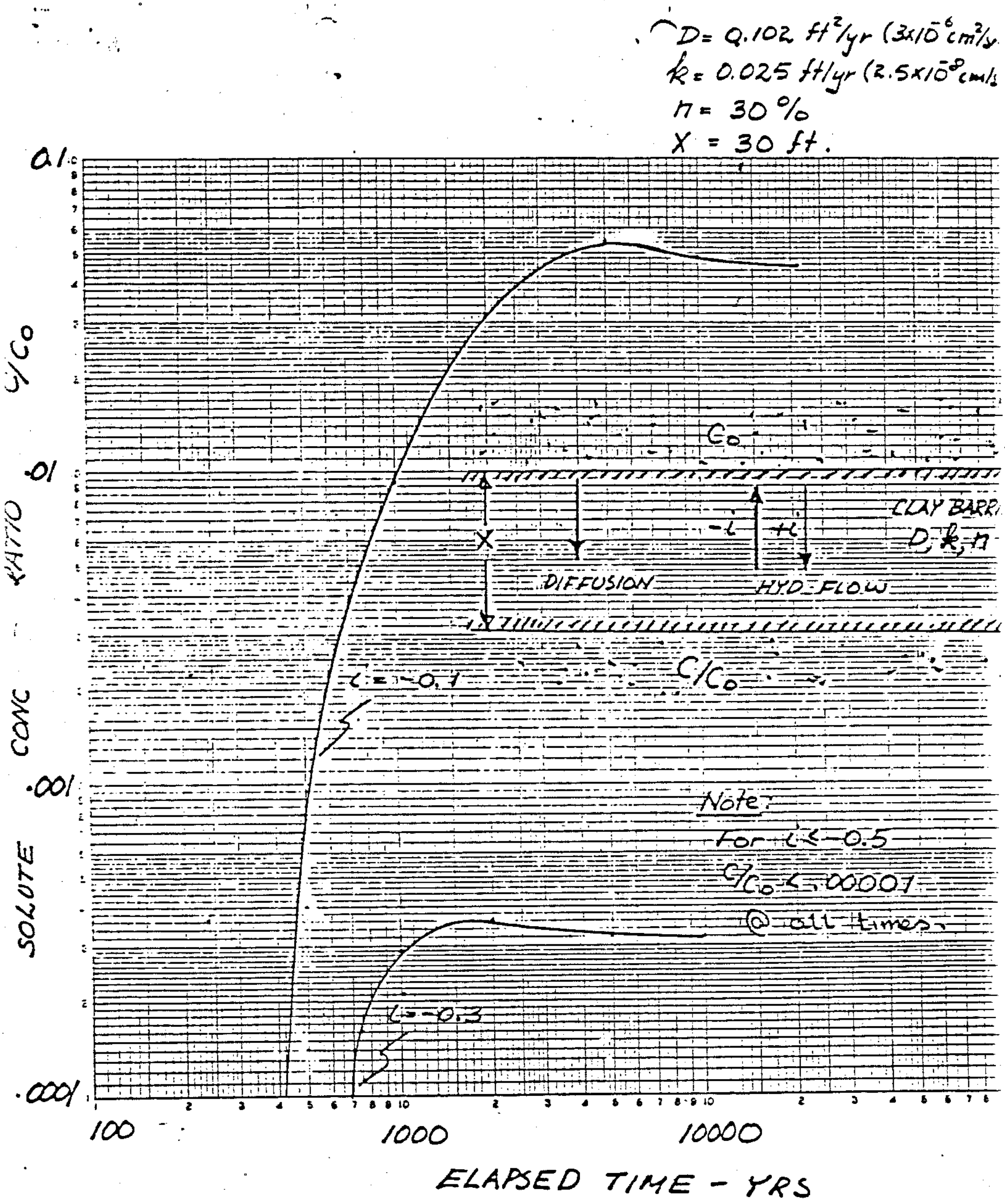
A copy of the computer program and typical output are enclosed. It is written in BASIC and is designed to be run on a personal computer. If you have any questions about the analysis, please feel free to contact me.

Sincerely,

Donald H. Gray

Donald H. Gray
Professor of Civil Engineering

Encl



Full Logarithmic, 3 × 3 Cycles

```
run
Porosity: 0.3
Permeability(ft/yr): .025
Diffusion Coef(ft /yr): 0.102
Wall Thickness: 30
Hydraulic Gradient: -0.3
Time(yrs): 500
---------------------------------------------------------
1st Argument(Y1)is:                        2.9756
1st Error Function is:                     0.9999
2nd Argument(Y2)is:                        1.22525
2nd Error Function is:                     0.9173
Exit/Source Concentration Ratio  (C/Co)is:                 8E-05
---------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 750
---------------------------------------------------------
1st Argument(Y1)is:                        2.78685
1st Error Function is:                     0.99979
2nd Argument(Y2)is:                        0.64312
2nd Error Function is:                     0.63658
Exit/Source Concentration Ratio  (C/Co)is:                 2.2E-04
---------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 1000
---------------------------------------------------------
1st Argument(Y1)is:                        2.72291
1st Error Function is:                     0.99973
2nd Argument(Y2)is:                        0.24754
2nd Error Function is:                     0.27399
Exit/Source Concentration Ratio  (C/Co)is:                 3.7E-04
---------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 2000
---------------------------------------------------------
1st Argument(Y1)is:                        2.80056
1st Error Function is:                     0.9998
2nd Argument(Y2)is:                        -0.70014
2nd Error Function is:                     0
Exit/Source Concentration Ratio  (C/Co)is:                 4.2E-04
---------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 5000
---------------------------------------------------------
1st Argument(Y1)is:                        3.43176
1st Error Function is:                     0.99998
2nd Argument(Y2)is:                        -2.10334
2nd Error Function is:                     0
Exit/Source Concentration Ratio  (C/Co)is:                 3.3E-04
---------------------------------------------------------
Continue Calculations (y/n) ? n
```

1704 Morton Street
Ann Arbor, MI 48104

16 February 1984

MINING PROPS.

22 FEB 84 8:20

Mr. David S. Miller
Mining Properties Department
Rouge Steel Company
3001 Miller Road
Dearborn, MI 48121

RE: Allen Park Clay Mine/Landfill

Dear Dave:

I have reviewed the memorandum dated January 23, 1984, from Terry McNiel, Technical Services Section, to Larry Aubuchon, Compliance Section, Detroit District, MDNR. The memorandum essentially raises the following objections to the findings and conclusions in my report, viz.,

Objection 1. There is no substantiation nor literature citations to show that organics present in the waste will not increase permeability.

Objection 2. The presence and possible effects of napthalene in the waste are disregarded.

Objection 3. Uncertainties remain about the actual composition and likely nature of the leachate.

Objection 4. The report does not address the question of compatibility between the following:

a) Leachate and leachate collection system components
b) Generated gases and clay cap.

In the opinion of the MDNR reviewer Objections 1,2,and 3 taken together mean that Specific Condition 5.A.4 (a) of Act 64 license is not satisfied. The reviewer goes on to say, however, that they (MDNR) would accept compatibility testing between actual leachate being generated and the on-site clay being used for containment. I will respond herein to these stated objections and opinion. Objection 4 which pertains to Specific Condition 5.A.4 (b) and (c) is outside the scope and original charge of my investigation.

Objection 1 is a version of the "guilty until proved innocent" syndrome. I understand and even sympathize with this approach in matters which deal with the release of potentially hazardous substances into the environment. There is, however, considerable substantiation in the published technical literature for the contention that organics present in low concentrations in aequous leachate will not increase the permeability of dense clays.

Leachate permeability tests on sand-clay columns packed to bulk densities within the range of densities of natural clays (Cartwright et al., 1977) have shown that permeability actually decreased with passage of leachate (containing organics). These tests were continued for periods up to nine months. Decreases were even more pronounced for raw, unsterilized leachate. In addition to permeability reduction from the passage of leachate, Griffin and Shimp (1976) have shown that heavy metal ions (Pb, Zn, Cd, Hg) are strongly attenuated by clay. Organics that were present in the leachate were only moderately attenuated by the clay; they did not increase hydraulic conductivity. We have also conducted long term leachate permeability tests ourselves on a silty clay almost identical in composition to the clay underlying the Allen Park Clay Mine/Landfill site (Gray, 1982) and found the same results, i.e., no increase in permeability was observed. A chemical analysis of the leachates used in all these permeability tests is attached. Note the presence of napthalene in one of the leachates--a constituent whose presence and influence the MDNR reviewer claimed we had not considered. (Note: Cited references are listed in an attachment to this letter report.)

It is important to emphasize again the fact that leachate permeability tests conducted by Anderson (1982) are totaly unrepresentative of conditions at the Allen Park site. These tests are often cited as an example of the deleterious influence of organic solvents on clay liner permeability. Anderson's tests are unrepresentative and irrelevant for the following reasons:

1. He used pure organic solvents. The leachate at the Allen Park Clay Mine/Landfill will be an aequous extract containing very low concentrations of organics.

2. He forced the solvents through clays at extremely high, positive gradients. Anderson used positive gradients ranging from 60 to 300. At the Allen Park site there will be negative (reverse) gradients ranging on the order of -0.3 (worst case) to -2.7.

Other objections can also be cited in regard to Anderson's test procedures and results. He used a rigid wall permeameter which permits channeling between sample and container. The recommended procedure to avoid this potential problem is to use a flexible, pressurized jacket. Large reported increases in permeability should be viewed with some skepticism when rigid wall permeameters have been employed.

Green et al. (1981) have investigated in great detail the charateristics of organic solvents that affect their rate of movement (permeability) in compacted clay. They measured the equilibrium permeability of three clays (a clay shale, a fire clay, and kaolinite) to the following solvents: benzene, xylene, carbon tetrachloride, trichloroethylene, acetone, methanol, glycerol, and water. Their study showed that it is the hydrophilic or hydrophobic nature of the solvent (as measured by the octanol/water partitioning coefficient or roughly by the dielectric constant) and not the viscosity/density ratio that is important in predicting a solvents rate of flow through clays. According to their findings water, which has a high dielectric constant, always exhibited the highest permeability. In addition, they found that the packed clay density is crucial in determining how permeable a clay will be to a given solvent. At high bulk densities (on the order of 115 pcf or 1.85 g/cc) the solvent characteristics became less important in differentiating permeability response.

Green _et al_. (1981) also observed that solvents of low dielectric constant (e.g. xylene and carbon tetrachloride) tended to cause shrinkage and cracking of some of the clays. This phenomenon, known as syneresis, can and eventually did cause an apparent permeability increase in some of the clays that were tested. The same phenomenon was reported by Anderson(1982) in some of his experiments. It must be emphasized again, however, that the effect has only been observed and reported when several pore volumes of _pure_, _low-dielectric_ organic solvents are forced at _very high gradients_ through clay columns. These conditions simply do not occur at the Allen Park Clay Mine/Landfill site.

On the contrary, the conditions at the Allen Park site are ideal for effective containment, viz.,

1. The site is underlain by a thick ($X \geq 25$ ft) section of dense, competent silty clay (γ_D = 115 pcf) with a very low hydraulic conductivity ($k = 2 \times 10^{-8}$ cm/sec)

2. A negative hydraulic gradient exists at the site as result of artesian conditions in the underlying aquifer. Even under worst case assumptions (viz., leachate levels rising to the top of the landfill) a negative gradient of -0.3 will still be present.

3. The leachate consists of very low concentrations of organic and inorganic solutes in an aqueous solution as opposed to a pure solvent.

Under these conditions advective transport or hydraulic seepage ceases to dominate pollutant movement across a clay barrier (see Gilbert and Cherry, 1983; Tallard, 1984). Instead, diffusion under chemical concentration gradients becomes more important, and it is this transport mechanism that must be evaluated carefully. I have dealt with this problem both in my original report and in my subsequent letter report to Mr. Mark Young, Wayne Disposal, Inc., dated 25 September 1983. I showed that even under worst case assumptions of no partitioning or attenuation of pollutants and minimum, negative hydraulic gradients breakthrought times would be on the order of thousands of years. Interestingly, if the calculations are repeated allowing the hydraulic conductivity or permeability to double or even triple, the breakthrough time increase even more because now the counter advective flow is more effective in opposing the downward diffusion of solutes along their concentration gradient.

I come now to the MDNR comments about requiring compatibility testing (whatever that means) between actual leachate and the clay liner material. Unfortunately, the procedure, rationale, etc. for such tests are not specified. What is being required ...that the leachate be forced under high hydraulic gradients through a thin sample of the silty clay? The results or significance of such a test would be ambiguous at best and meaningless at worst in this case. In my opinion, such tests would be an exercise in futility and irrelevance given the condition and circumstances at the Allen Park Clay Mine/Landfill site.

Breakthrough times in diffusion controlled transport are extremely sensitive to thickness of the barrier. In order to replicate conditions in the field at Allen Park, compatibility or flow tests should be run on a sample column 25 feet high under a <u>negative</u> gradient no less than -0.3. After a wait time of thousands of years such a test would merely confirm what is already demonstrable.

It is my professional opinion that in this instance the requirement for compatibility testing and concern over permeability is a diversion from the real issue which is the likelihood of diffusion transport of solute across the clay. I have shown that this will not be a problem at the Allen Park Clay Mine/Landfill site because of the thickness, competency, and density of the underlying clay together with the existence of a negative gradient.

I find it baffling that MDNR can approve a thin, clay slurry wall for a toxic waste site (see Consent Judgment, U.S. District Court, U.S. Envl. Protection Agency and The State of Michigan, Plaintiffs, vs. Velsicol Chemical Corp., Defendant) based on meagre and inadequate evaluation whilst insisting on irrelevant tests for a thick, natural clay containment system at Allen Park that is ideal in nearly every respect.

Sincerely,

Donald H. Gray

Donald H. Gray
Professor of Civil Engineering

Attachments

ATTACHMENT NO. 1 - CITED REFERENCES

Anderson, D. (1982). Does landfill leachate make clay liners more permeable? Civil Engineering, ASCE, Vol. 52, pp. 66-69

Cartwright, K., Griffin, R.A., and Gilkeson, R.H. Migration of landfill leachate through glacial tills, Groundwater, Vol. 15, No. 4, pp. 294-305

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Gray, D.H. (1982). Influence of leachate on clay liner permeability, Wayne Disposal landfill site, Report prepared for Wayne Disposal, Inc., September 1982

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Griffin, R.A. and Shimp, N.F. (1976). Attenuation of pollutants in municipal landfill leachate by clay minerals, Cincinnati Ohio: Final Report for U.S. Envl Protection Agency, Contract 68-03-0211

Tallard, G. (1984). Slurry trenches for containing hazardous wastes, Civil Engineering, ASCE, Vol. 54, No. 2, pp. 41-45

ATTACHMENT NO 2

Table 2. Chemical Analysis of Landfill Leachates

Analysis	DuPage County Landfill-mg/l	Wayne Disposal Landfill-mg/l
Na	748	3400
K	501	-
Ca	47	46
Mg	233	370
Cu	<0.1	0.55
Zn	18.8	5.0
Pb	4.46	0.91
Cd	1.95	0.10
Ni	0.3	0.40
Hg	0.0008	0.010
Cr	<0.1	0.31
Fe	4.2	7.77
Mn	<0.1	-
Al	<0.1	-
NH_4	862	1540
As	0.11	0.0044
B	29.9	<0.005
Si	14.9	-
Cl	3484	5800
SO_4	<0.1	200
NO_3	-	<0.1
HCO_3	-	6920
COD	1340	2160
TOC	-	2500
TSS	-	512
pH	6.9	7.6
Spec. Cond. (mmhos/cm)	10.2	28.0
Equiv. TDS	6528	17,920
Organics:		
organic acids (phenol)	0.3	3.6
toluene	-	0.45
napthalene	-	0.44
chlorobenzene	-	0.008

EXHIBIT E

L. M. MILLER & ASSOCIATES
CONSULTING ENGINEERS & GEOLOGISTS

2500 PACKARD RD., SUITE #106
ANN ARBOR, MICHIGAN 48104

June 17, 1982

Rouge Steel Company
Division of Mining Properties
3001 Miller Road
P.O. Box 1699
Dearbor, Mi 48121

Attention: Mr. David Miller

Re: Allen Park Clay Mine Seismic Survey

Dear Mr. Miller:

As per your request a seismic study was performed at the Allen Park Clay Mine area in Allen Park, Michigan. The purpose of this study was an attempt to determine the depth to bedrock in the area immediately below the excavated pit at the disposal area.

Keeping consistent with previous seismic work accomplished in the area these stations were numbered 4, 5 and 6. Stations 4 and 5 were completed on the excavated pit floor, 4 being on the eastern half and 5 on the western side of the pit floor, with station 6 directly to the north of the pit up on approximately the existing surface elevation, some 30 to 40 feet above the pit floor. Plots of the data collected are included and indicate both the velocities of the layers and the depths to the layer interfaces.

Station 4 resulted in the best data collected at the site, and shows a three-layer case. A low velocity (1428 ft/sec) layer is underlain by a very consistent layer with a velocity of 5233 ft/sec, extending to a depth of 57 feet below the pit floor where it is underlain by a much higher velocity (12,808 ft/sec) layer. These values are very typical of a dense clay layer underlain by a hard limestone type material. The rather good fit of the data to a line would indicate very consistent materials, however, the irregularities near the 57 foot contact indicate that this interface is not as sharp a transition and hence it represents more of a minimum depth to this interface.

At Station 5 area surface topography was rough and inconsistent which resulted in limited data being collected. In one area a very steep depression was encountered on the surface which the shock wave source worked in. This abrupt lowering of the elevation causes a decrease in the time it takes to the shock wave to travel through the subsurface. Therefore, the best fit line was drawn through only those points where the shock wave source was at the approximate same elevation. Had the elevation been consistent, the travel times for those distances, which were lower, would have been increased in the direction towards this line.

Station 5 showed approximately the same subsurface conditions as did 4, with a depth to the bedrock being indicated at 70 feet below the pit floor. Station 6 was run at a much higher elevation than that of the pit floor, and very soft wet surface conditions were found. These types of surface conditions do not allow for seismic shock waves to propogate as the material tends to absorb much of the energy and transmit this energy directly across the surface rather than down into the earth. This data indicates again a rather consistent layer with a velocity typical of a dense clay. As a rule of thumb, seismic tests measure in depth roughly one-third the distance from the energy source to the geophone. Using this rule the limits of our data would be to a depth of approximately 45 feet for the clay layer and would obviously extend until the next layer is encountered.

We hope that this information is useful to you. If any further information on subsurface conditions is needed, it should be noted that there is enough room in the bottom of the excavated pit for an electrical resistivity test to be run. The problems caused by surface conditions could be avoided and with the large contrast in the subsurface materials this test would most likely work well.

If we can be of any further assistance, please let us know.

Very truly yours,

L. M. MILLER & ASSOCIATES

Timothy P. Wilson

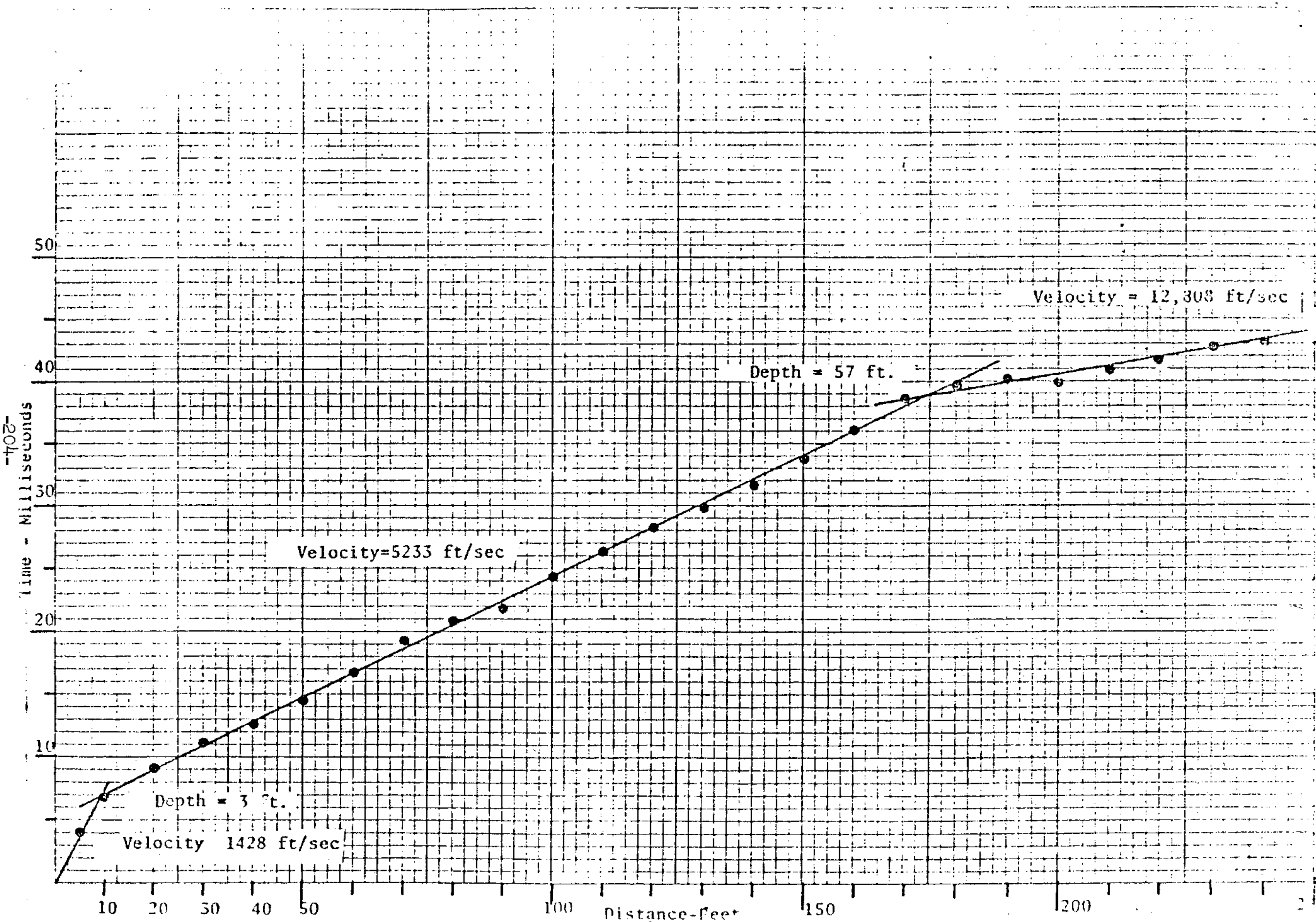
Timothy P. Wilson, Geologist

TPW:hrh

Attachments as mentioned above.

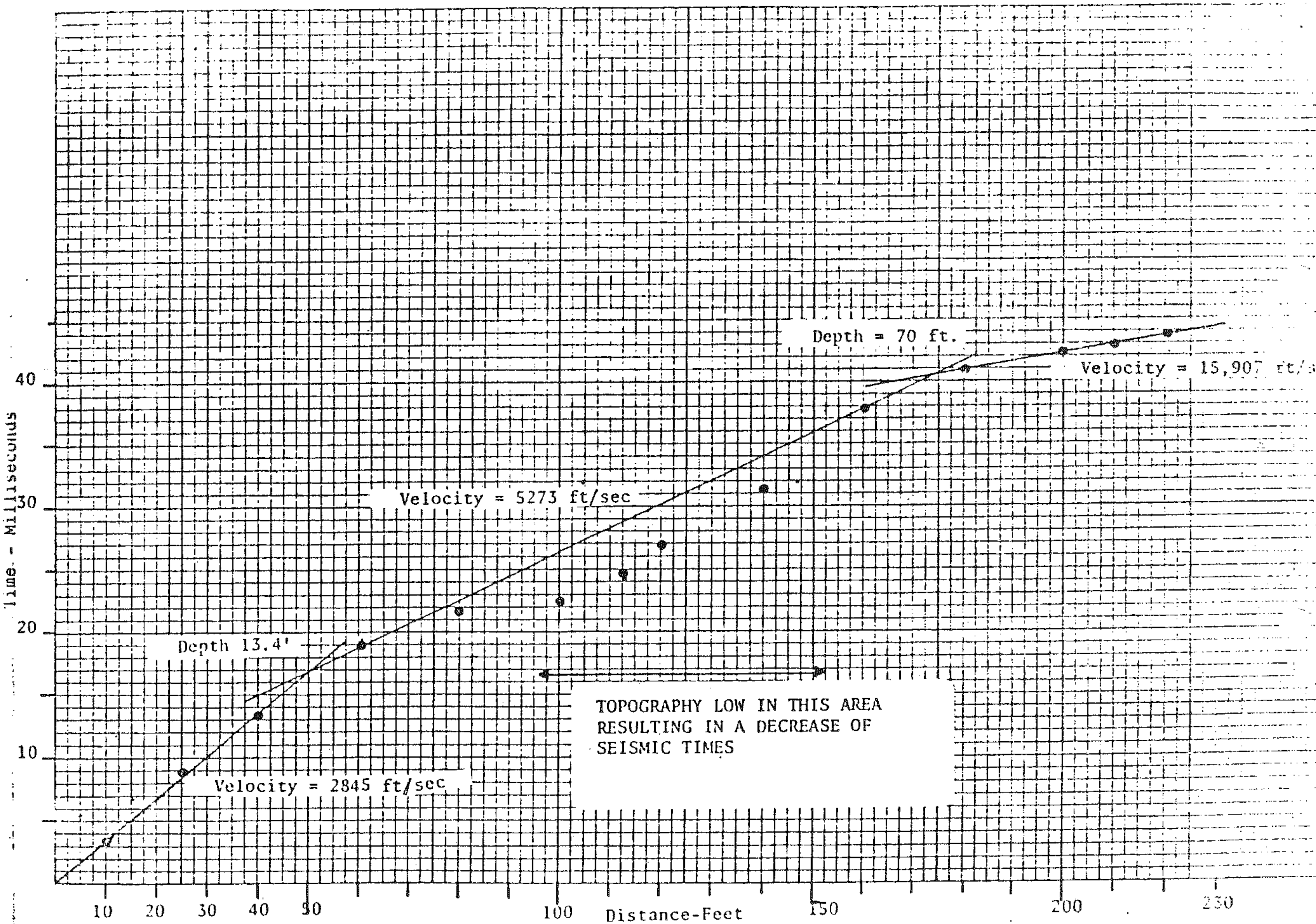
ALLEN PARK CLAY MINE
SEISMIC STATION #4

L. M. MILLER & ASSOCIATES

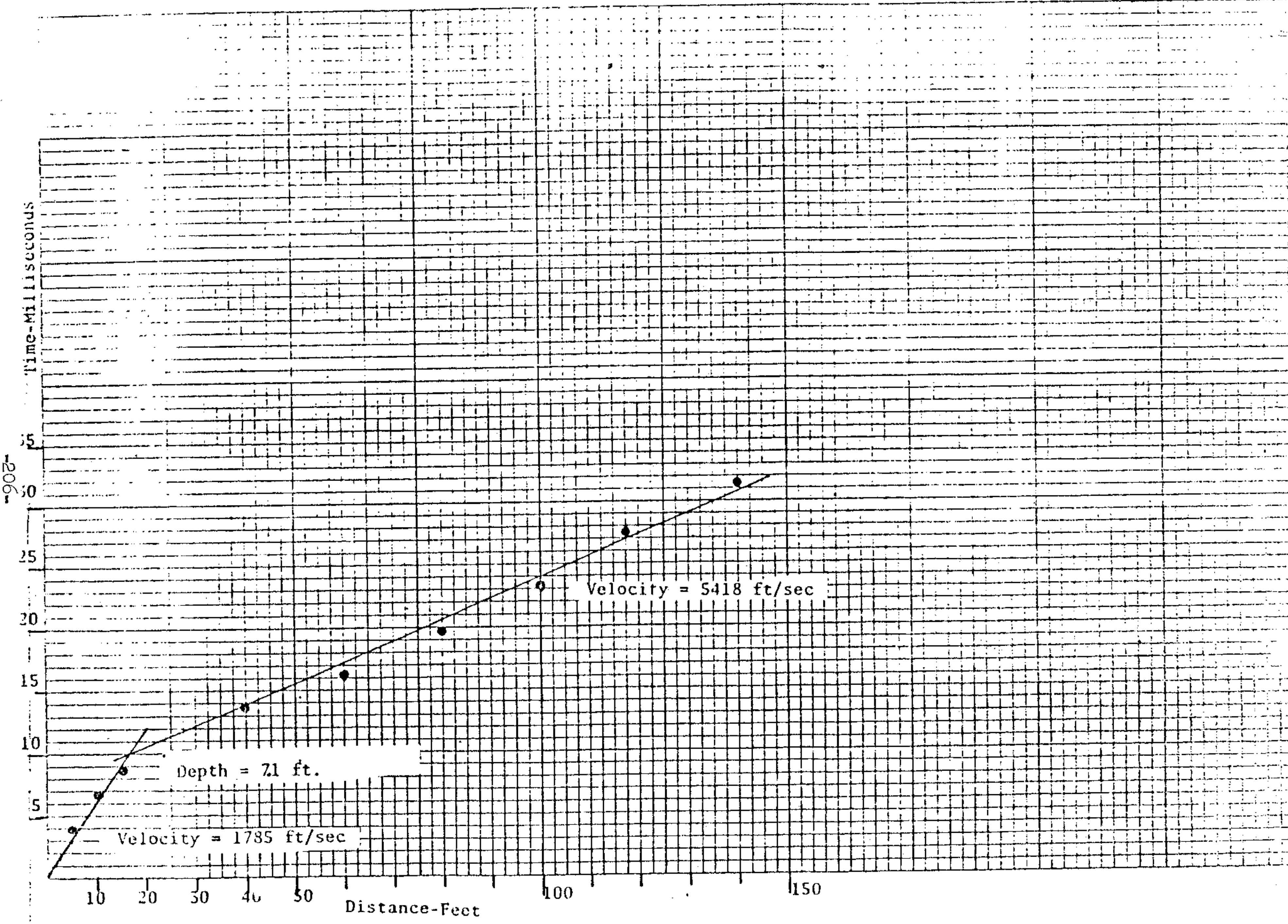


ALLEN PARK CLAY MINE
SEISMIC STATION #3

L. M. MILLER & ASSOC



SEISMIC STATION #6



MICHIGAN TESTING ENGINEERS, INC.
24355 CAPITOL AVENUE • DETROIT, MICHIGAN 48239
PHONE: (313) 255-4200

SOILS EXPLORATIONS AND FOUNDATION ENGINEERING
MATERIALS TESTING AND INSPECTION
NON-DESTRUCTIVE TESTING and MATERIALS EVALUATION

June 25, 1982

Michigan Department of Natural Resources
Resource Recovery Division
P.O. Box 30028
Lansing, Michigan 48909

Attn: Mr. James Janiczek

Subject: Allen Park Clay Mine
Allen Park, Michigan
MTE File #406-15046

Gentlemen:

As requested, we have reviewed the above referenced file to determine the degree of saturation of the subsoils on the site.

The following basic soil relationships were used in this review:

$$s = \frac{wG_s}{e}$$

$$e = \frac{G_s}{\gamma_d} - 1$$

$$w = \frac{W_w}{W_s}$$

Where: s = degree of saturation (%)
w = moisture content of soil (%)
e = void ratio
W_w = weight of water
W_s = weight of solids
γ_d = dry unit weight of soil
G_s = specific gravity of solids (assumed to be 2.65 to 2.68)

Utilizing these procedures, our calculations indicate the gray silty clays on the Allen Park Clay Mine to be 100% saturated.

If there are any questions, please do not hesitate to call.

Very truly yours,

MICHIGAN TESTING ENGINEERS, INC.

Randall DeRuiter

Randall DeRuiter

RD/ksb

cc: D. Miller, Ford Motor Company
W. Tomyn, Wayne Disposal

EXHIBIT G

WILLIAM G. MILLIKEN, Governor

DEPARTMENT OF NATURAL RESOURCES

HOWARD A. TANNER, Director

RESOURCE RECOVERY DIVISION
P.O. BOX 30028
LANSING, MI 48909

ADMINISTRATION/RESOURCE RECOVERY SECTION
517/373-0540

PLANNING SECTION/ HAZARDOUS WASTE SECTION
517/373-1818

GEOLOGY SECTION
517/373-0907

November 4, 1981

Mr. Marshall Austin
Michigan Testing Engineers, Inc.
24355 Capitol Avenue
Detroit, Michigan 48239

RE: Permeability testing of clay soils
Allen Park Clay Mine; Allen Park, Michigan
Wayne County

Dear Marshall:

Based on the review of the soil tests performed (grain size analysis, atterberg limits and permeability) on the clay at the Allen Park Clay Mine Landfill, it is the feeling of this office that the materials are uniform enough that no further permeability testing will be required. This portion of our evaluation has been satisfied with the information submitted.

If you have any questions, please feel free to call.

Very truly yours,

RESOURCE RECOVERY DIVISION

James Janiczek

James Janiczek
Geologist

JJ:nm

cc: Shakir/Belobraidich
Mark Young, Wayne Disposal
Wayne County Health Department

~~Exhibit #~~
MID 980 568 711
Exhibit H

NEYER, TISEO & HINDO, LTD.

CONSULTING ENGINEERS AND GEOLOGISTS
30999 Ten Mile Road • Farmington Hills, Michigan 48024 • (313) 471-0750

REPORT ON PIEZOMETER INSTALLATION

PROJECT NO:	84185 OW
DESIGNATION:	Allen Park Clay Mine Landfill
LOCATION:	Allen Park, Michigan
OWNER:	Ford Motor Company
DATE:	March 29, 1985

228-28

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS AND GEOLOGISTS
30999 Ten Mile Road • Farmington Hills, Michigan 48024 • (313) 471-0750

March 29, 1985
Project No. 84185 OW

Mr. David S. Miller
Mining Properties Department
Rouge Steel Company
3001 Miller Road
Dearborn, Michigan 48121

RE: Vertical Hydraulic Gradients
Allen Park Clay Mine Landfill

Dear Mr. Miller:

In accordance with your request, we have completed the installation of piezometers and the evaluation of the hydraulic gradients in the natural clay deposit at the Allen Park Clay Mine Landfill. This work was performed in general accordance with our proposal, dated October 22, 1984, and was authorized by you on January 16, 1985. The information, evaluations and conclusions presented herein have been prepared according to generally accepted geotechnical engineering practices and are provided for the exclusive use of the Ford Motor Company, the U.S. Environmental Protection Agency and the Michigan Department of Natural Resources.

BACKGROUND

The general subsoil profile at the site consists of an upper sand, replaced by fill in some areas, underlain by an extensive silty clay deposit which is, in turn, underlain by a lower sand deposit. This lower sand is sometimes found in conjunction with a highly overconsolidated clayey silt deposit, locally termed hardpan. On the basis of the information obtained during the piezometer installation described herein as well as information presented in a report entitled Hydrogeologic Study-Allen Park Clay Mine, by Michigan Testing Engineers (MTE) and dated November 24, 1981, the thickness of these deposits at the location of the three piezometer nest locations can be described as follows:

Upper Sands - 3 to 7 feet
Silty Clay - 65 to 70 feet
Lower Sands - 3 to 6 feet or more

Groundwater levels have been monitored in the upper and lower sands at the site for at least several years (MTE, 1981). These levels indicate that there is a saturated zone in the upper sand, at least on a seasonal basis. The lower sand contains groundwater under artesian pressure, with piezometric levels at or above the ground surface.

Based upon these data, an upward hydraulic flow gradient has been considered by Rouge Steel Company (in permit submittals) to exist at the site. In other words, groundwater apparently flows from the lower sand upward through the clay deposit to the upper sand. Michigan Department of Natural Resources (MDNR) staff have requested that the existence and direction of natural flow gradients within the clay deposit at the site be confirmed with the use of three piezometer nests wherein piezometric pressures at various depths within the clay deposit would be monitored. Because of this request by MDNR staff, Rouge Steel Company retained Neyer, Tiseo & Hindo, Ltd. (NTH) to install and monitor such a piezometer system.

PIEZOMETER SYSTEM

The piezometer system consists of a piezometer installed near the top, middle and base of the natural clay deposit beneath the site. This grouping of three, considered a "nest", has been duplicated at three different locations on the site, resulting in a total of nine piezometers set in the clay deposit. Each nest is located near an existing monitoring well pair, consisting of a shallow and a deep well. Their approximate locations are presented on the Piezometer Nest Location Plan, Plate 1. Each piezometer is identified first by the number of the well pair and second by position in the nest, 1 indicating deep with 3 being shallow.

The drilling and piezometer installation was performed by West Michigan Drilling during the period of February 13 through February 20, 1985 under the full-time supervision of personnel from NTH. Ground surface and top of casing elevations have been provided by Rouge Steel Company.

A trailer-mounted CME-55 drilling rig with 8-inch diameter hollow-stem augers was used to drill the piezometer holes. A limited number of soil samples were recovered to identify the depth of the upper sand/clay interface and to verify the soil type at the placement depth. The locations of samples recovered are reported on the logs.

Soil conditions encountered in the test borings were visually evaluated in the field and are presented on the individual Logs of Piezometer Installation, Figures 1 through 9. In addition, the logs present data relating to drilling methods, personnel involved and grouting procedures. The stratification lines shown on the logs represent the approximate boundary between soil types but the transition may be gradual. General Notes describing the nomenclature used in the logs are also included herein as Exhibit 1.

The general procedure for the piezometer installation involved drilling down to a depth of one foot below the desired tip

placement elevation. A sample was taken at this point to verify the characteristics of the soil within which the piezometer was to be installed. The augers were then removed until only ten or fifteen feet remained in the hole. Silica sand was then poured into the bottom of the hole until the sand backfill reached the desired tip elevation. The piezometer was inserted and an additional two to three feet of the hole was filled with sand. Bentonite pellets were placed to provide a seal, in some cases, and the hole was then grouted to the ground surface with non-shrinking cement grout. A four foot section of 5-inch diameter Schedule 40 PVC casing was positioned at the ground surface to protect the leads of the piezometers.

The piezometers are pore-pressure transducers which convert fluid pressure in the soil to pneumatic pressure which can be monitored at the ground surface using a compressed nitrogen source. They are a pneumatic, diaphragm type with a Norton Alundum filter and triple tubing and are manufactured by SINCO, Model No. 514178.

PIEZOMETRIC DATA EVALUATION

The piezometers and associated well pairs were monitored by personnel from NTH on several occasions. This data is presented in Table 1. The data obtained on the last date shown in Table 1 indicates that the pore water pressures adjacent to each piezometer had achieved near-equilibrium or stability after having been temporarily disturbed during drilling for the piezometer installations. This latter set of data has therefore been chosen for presentation in Plates 2 through 4, entitled Piezometric Data Illustration, Nest No. 2, 5 and 10, respectively. Note that in preparation of these illustrations, the shallow wells have been depicted as yielding water levels representative of the water levels in the upper sand even though they were completed in clay. This is considered appropriate because the available data (MTE, 1981) on these shallow wells indicates that they were constructed with a sand-filled borehole annulus, thus effecting a hydraulic connection between the upper sand and the shallow well screens. In addition, the upper sand and lower granular deposits were assumed to possess little or no vertical hydraulic gradient.

Evaluation of the data presented on Plates 2 through 4 yields several important observations:

- A pronounced upward hydraulic gradient is apparent at all three locations.

TABLE 1: PIEZOMETRIC ELEVATIONS
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

Date	2-1	2-2	2-3	MW-2 Deep	MW-2 Shallow	5-1	5-2	5-3	MW-5 Deep	MW-5 Shallow	10-1	10-2	10-3	MW-10 Deep	MW-10 Shallow
2-15-85	-	-	-			548.2	580.0	587.1			-	-	-		
2-18-85	-	-	-			563.4	584.1	590.5			-	-	-		
2-19-85	-	-	-			568.9	584.6	592.9			541.5	589.4	-		
2-20-85	578.2	586.9	-			573.3	586.9	591.2			554.0	590.3	582.2		
2-21-85	589.6	588.3	583.3			575.9	586.9	591.2			565.5	590.3	583.6		
2-28-85	-	-	-			587.4	589.3	*			-	-	-		
3-01-85	593.7	591.0	585.5		586.3	589.1	590.5	591.7		596.5	594.2	590.2	587.0	594.3	590.0
3-08-85	594.4	591.0	585.8			592.5	590.2	592.4			595.1	591.1	587.0		
3-11-85	595.1	590.7	586.5	599.7	586.7	594.1	590.9	591.9	604.2	596.4	595.3	591.1	587.4	594.4	589.9
3-22-85	595.3	591.0	586.7		580.6	596.3	593.2	591.7		595.7	595.5	591.1	587.4	594.6	588.0

*Ran out of N_2

- The upward flow gradient in the clay deposit is very nearly linear, suggesting a somewhat homogeneous deposit, at least with regard to vertical hydraulic conductivity. Similarly, all three locations yield upward hydraulic gradients that are of the same general magnitude.

- There appears to be some discontinuity of the hydraulic gradient with regard to piezometric levels in the upper and lower sand, most probably due to seasonal variability.

To elaborate, it can be seen that the estimated upward hydraulic gradient in Nest Nos. 2, 5 and 10 are 0.21, 0.11 and 0.20 ft./ft., respectively, based solely upon the piezometric data in the clay deposit. If we estimate the upward hydraulic gradient on the basis of the piezometric levels in the upper and lower sand deposits, these values are 0.19, 0.12, and 0.10, respectively. The differences between these two sets of hydraulic gradient data may be related to higher than normal water levels in the upper sand due to the seasonal weather conditions (snowmelt) which preceded the acquisition of the subject data. Hence, the hydraulic gradients based upon the piezometric data in the clay deposit most probably reflect the "normal" conditions, since these piezometric levels should be far less responsive to seasonal variations.

The deep well at Nest No. 10 is yielding water levels lower than expected on the basis of the piezometric levels observed in the clay. When originally installed in March, 1978, this well was reported (MTE, 1981) to exhibit piezometric levels near Elevation 602. This would correspond very well with the piezometric data in the clay. According to information from Rouge Steel Company, the piezometric level in this well dropped suddenly in 1982. The well was subsequently damaged in the spring of 1983. Hence, it is impossible to ascertain from available data whether the piezometric level currently observed in this well is erroneous.

The hydraulic gradients depicted on Plates 2 through 4 can be used to estimate a piezometric level at the same elevation in each location. Choosing Elevation 560 for instance, such an estimation yields piezometric levels of 589.2, 592.6, and 589.7 at Nest Nos. 2, 5, and 10, respectively. This suggests that a very gradual horizontal hydraulic gradient may exist within the clay deposit, at least with respect to the date of piezometer monitoring. The direction of this gradient is essentially northward. However, it should be noted that the possible velocity of flow and/or quantity of flow in a horizontal

direction within the clay deposit due to this gradient would be very small, especially in comparison to vertical migration or horizontal flow in the underlying granular deposit. It should also be noted that the past excavation and filling activities on the site have, or will, distort horizontal and vertical flow conditions in the clay deposit in the immediate vicinity of the excavations.

In a report entitled "Containment Integrity of Allen Park Clay Mine/Landfill" (July, 1983), Dr. Donald H. Gray discussed the upward hydraulic gradients at the subject site, with particular emphasis on the potential for downward contaminant migration despite upward hydraulic gradients. In that report, he evaluated such potential contaminant migration under upward hydraulic gradients imposed by the landfill excavation. He went on to discuss a "worst case" where the upward gradient would be approximately 0.3 ft./ft. if leachate levels in the landfill were allowed to reach the ground surface.

The data presented herein indicate upward hydraulic gradients through the native, undisturbed clay deposit to be roughly 0.1 to 0.2 ft./ft. If the thickness of the clay deposit is reduced due to excavation and leachate levels within the landfill are precluded from exceeding the water level in the sand at the surface of the site, then the imposed upward gradients will approximate or exceed his "worst case", i.e. his lowest gradient. Hence, maintenance of leachate collection systems will help assure that vertical flow beneath the landfill cells is upward, with induced hydraulic gradients similar to those presented by Dr. Gray (1983).

If you have any questions, please do not hesitate to contact us.

Very truly yours,

NEYER, TISEO & HINDO, LTD.

Liane J. Shekter

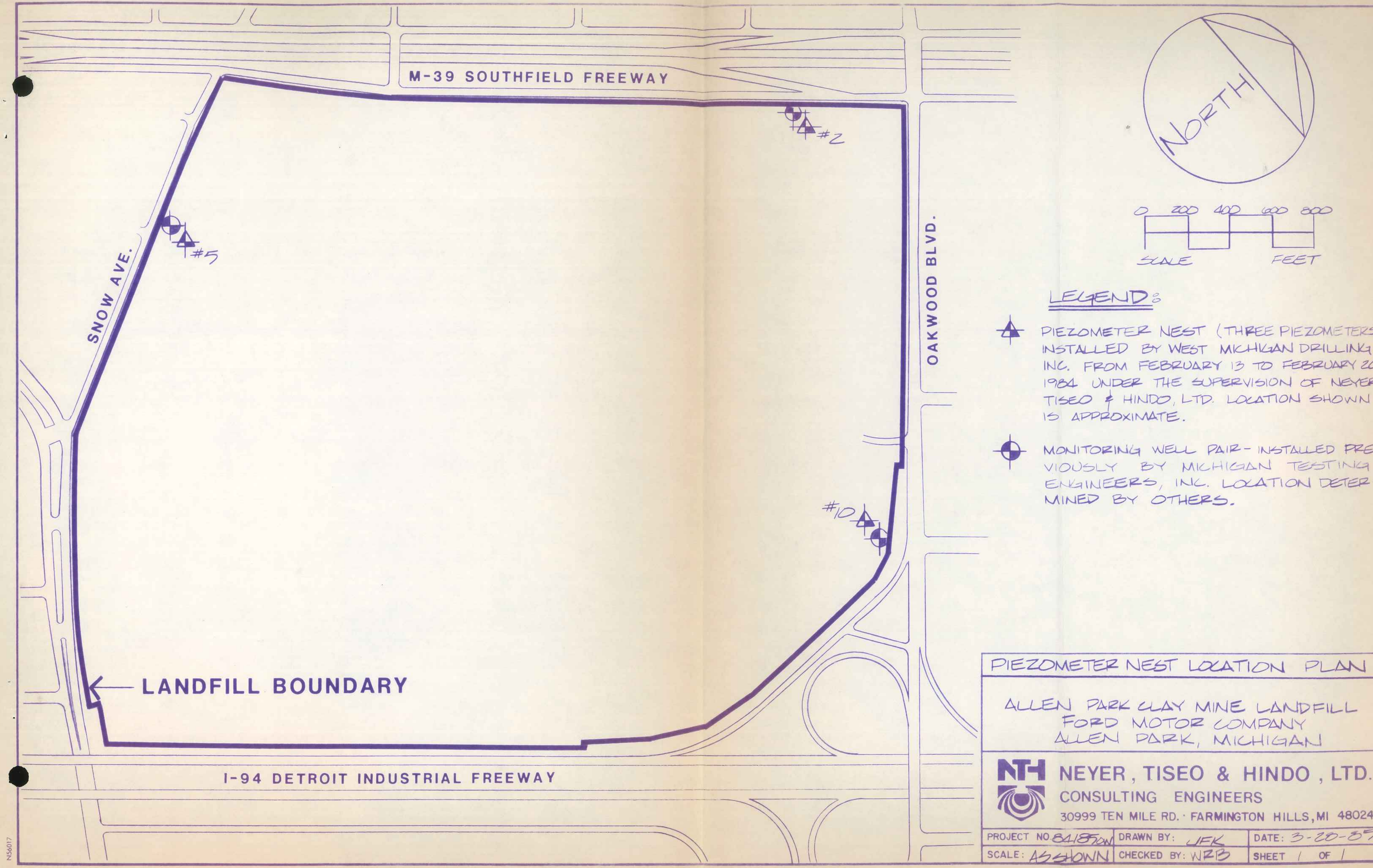
Liane J. Shekter

Wayne R. Bergstrom

Wayne R. Bergstrom, P.E.

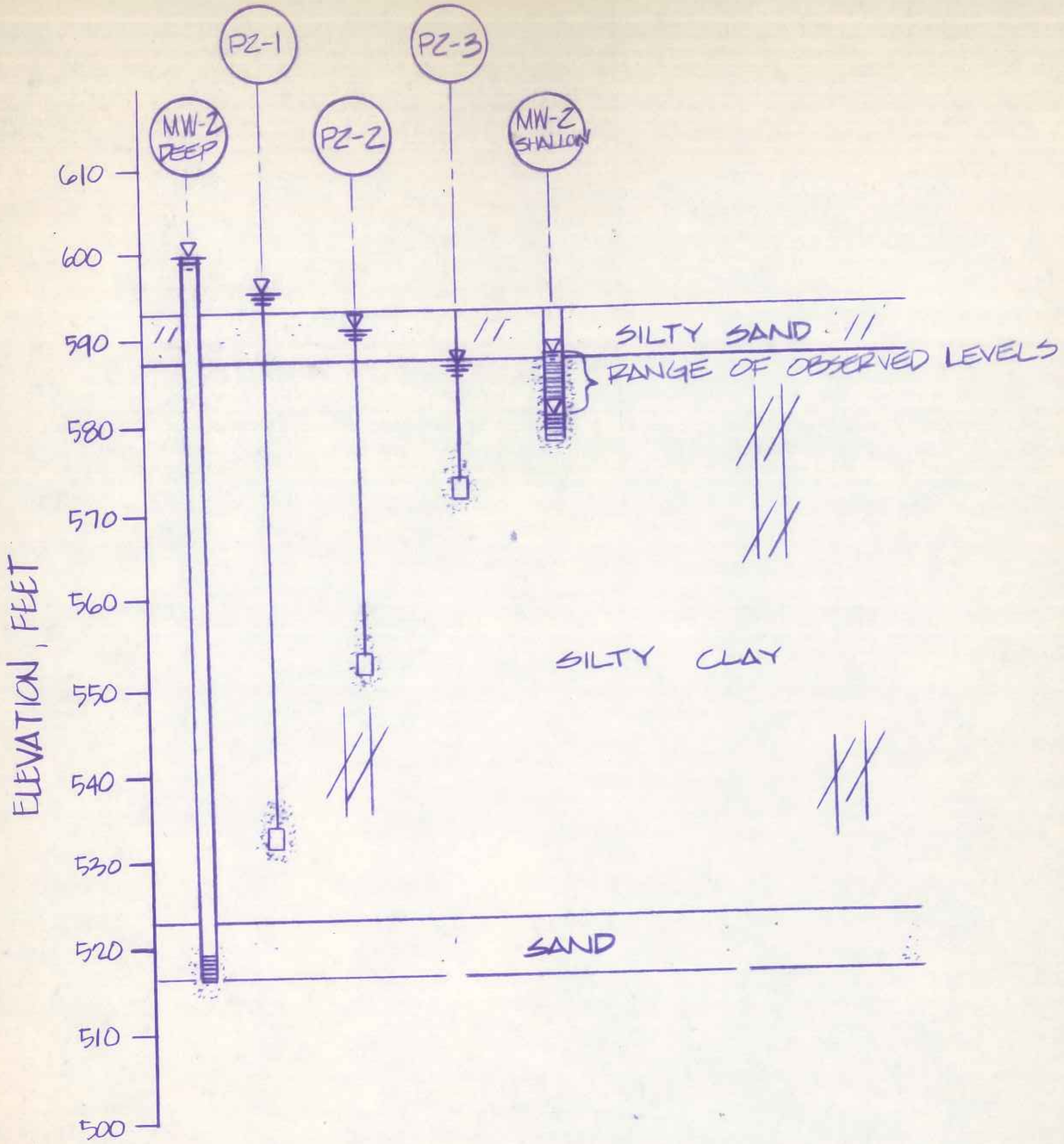
LJS/WRB/pp
Attachments

LIST OF PLATES AND FIGURES

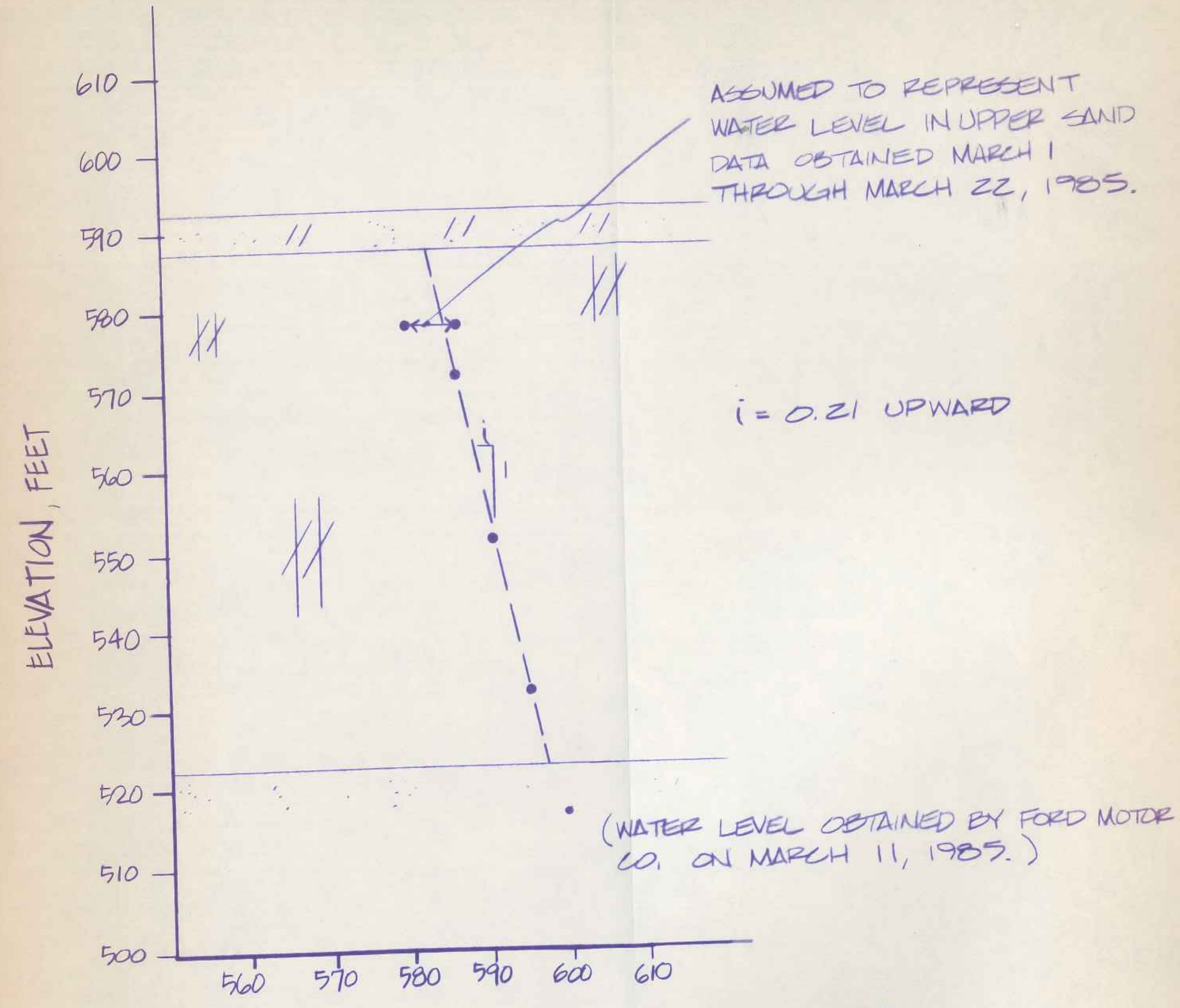


M-39 SOUTHFIELD FREEWAY
SNOW AVE.
OAKWOOD BLVD.
#2
#5
#10
LANDFILL BOUNDARY
I-94 DETROIT INDUSTRIAL FREEWAY
NORTH
0 200 400 600 800
SCALE FEET
LEGEND:
PIEZOMETER NEST (THREE PIEZOMETERS) INSTALLED BY WEST MICHIGAN DRILLING INC. FROM FEBRUARY 13 TO FEBRUARY 20, 1984 UNDER THE SUPERVISION OF NEYER, TISEO & HINDO, LTD. LOCATION SHOWN IS APPROXIMATE.
MONITORING WELL PAIR - INSTALLED PREVIOUSLY BY MICHIGAN TESTING ENGINEERS, INC. LOCATION DETERMINED BY OTHERS.
PIEZOMETER NEST LOCATION PLAN
ALLEN PARK CLAY MINE LANDFILL
FORD MOTOR COMPANY
ALLEN PARK, MICHIGAN
NTH
NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD. · FARMINGTON HILLS, MI 48024
PROJECT NO. 84185 OW
DRAWN BY: JFK
DATE: 3-20-85
SCALE: AS SHOWN
CHECKED BY: WRB
SHEET 1 OF 1

PLATE 1



SCHEMATIC OF PIEZOMETRIC DATA



PIEZOMETRIC (WATER LEVEL) ELEVATION, FEET

NOTES:

1. PIEZOMETRIC DATA OBTAINED BY NEYER, TISEO & HINDO, LTD. ON MARCH 22, 1985, EXCEPT AS NOTED.
2. PIEZOMETERS (DENOTED BY "P") WERE INSTALLED BY NEYER, TISEO & HINDO, LTD. WELLS WERE INSTALLED BY OTHERS.
3. HORIZONTAL POSITIONS OF WELLS AND PIEZOMETERS IN SCHEMATIC AT LEFT ARE FOR ILLUSTRATION ONLY.
4. SUBSURFACE PROFILE IS BASED UPON DRILLING RECORDS AND IS GENERALIZED.

PIEZOMETRIC DATA ILLUSTRATION, NEST No. 2

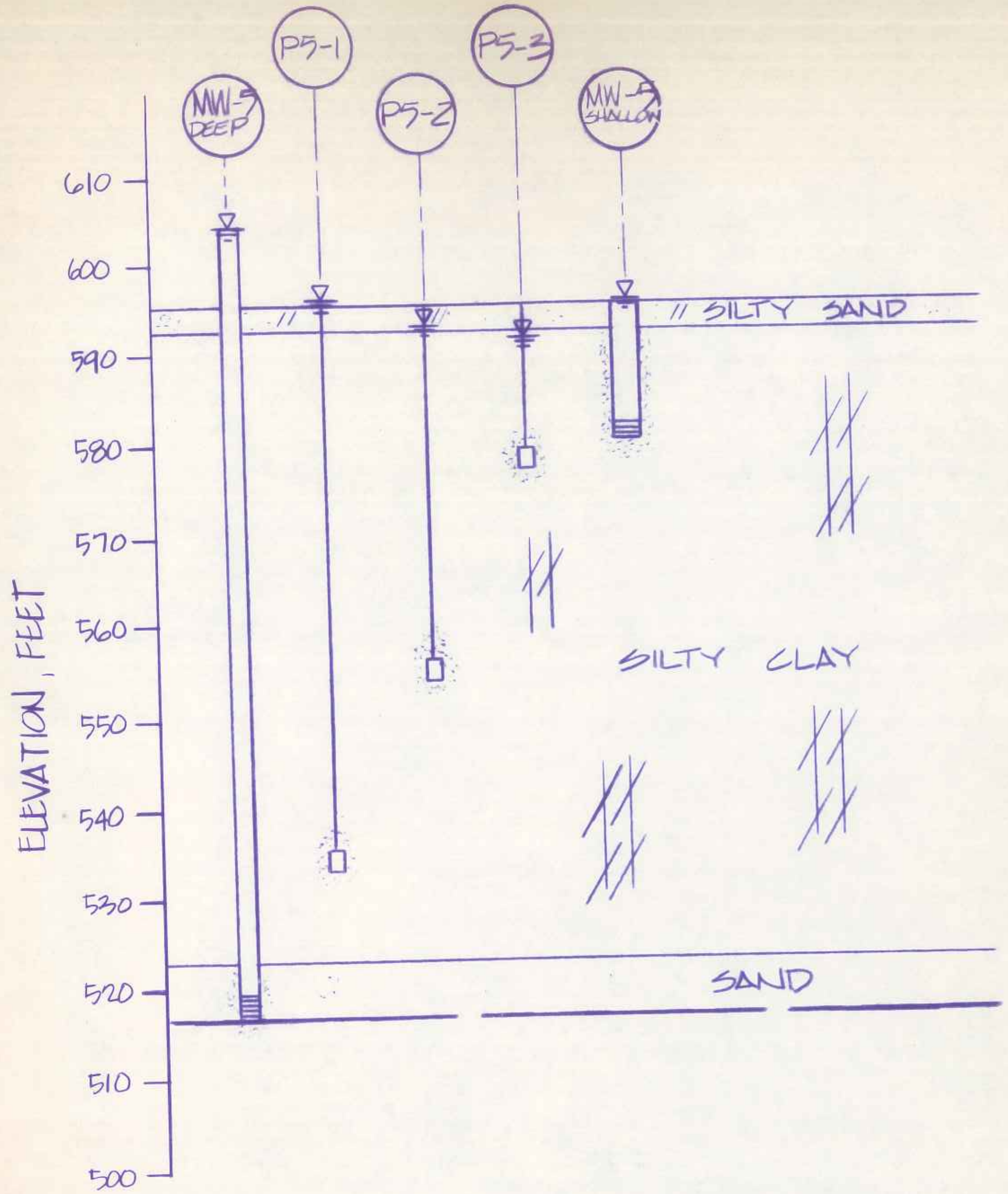
ALLEN PARK CLAY MINE LANDFILL
FORD MOTOR COMPANY
ALLEN PARK, MICHIGAN

NTH NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD. · FARMINGTON HILLS, MI 48024

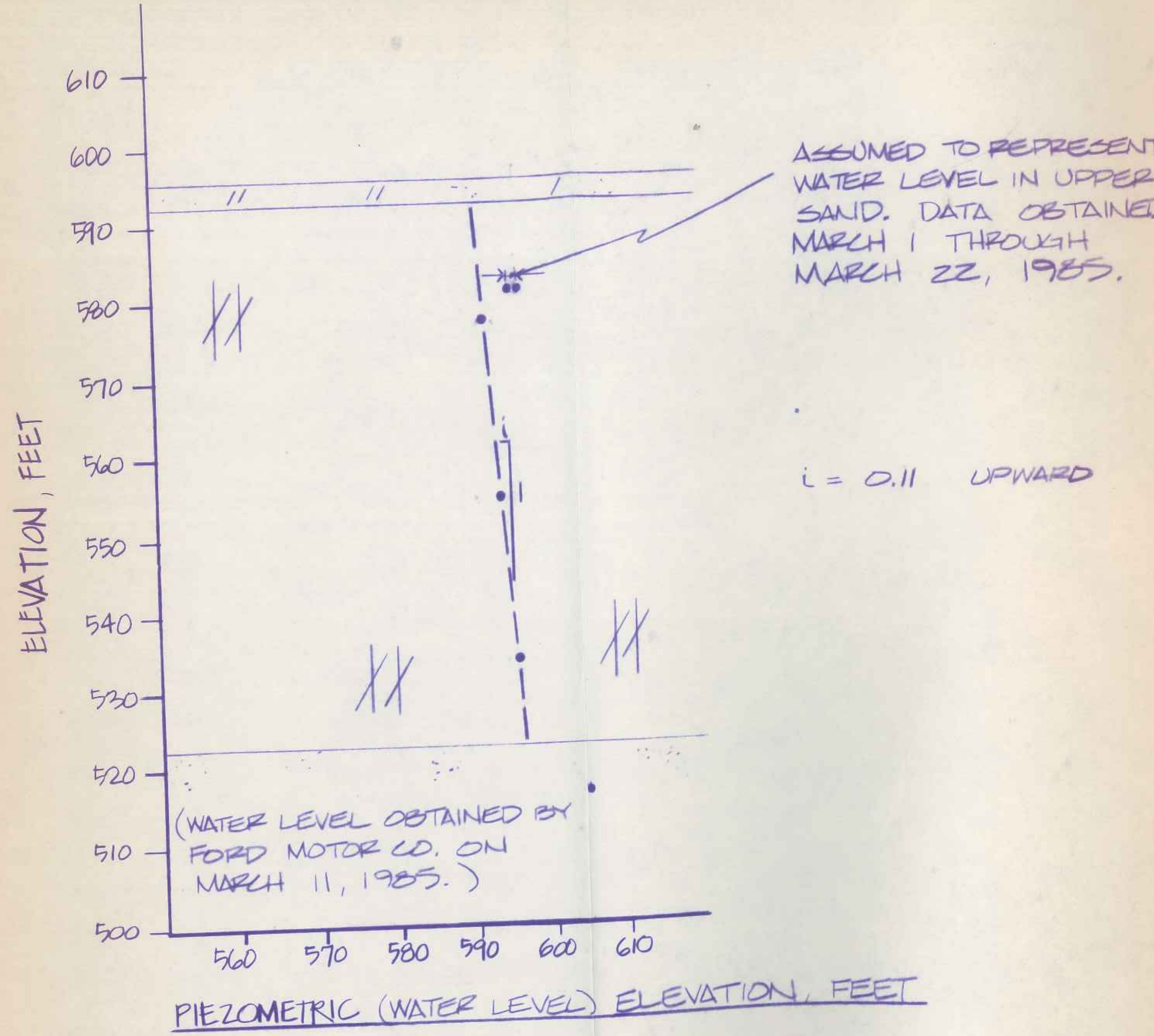
PROJECT NO.: 84185	DRAWN BY: JFK	DATE: 3-28-85
SCALE: NONE	CHECKED BY: WRB	SHEET 1 OF 1

PLATE 2

N56017



SCHEMATIC OF PIEZOMETRIC DATA



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3. HORIZONTAL POSITIONS OF WELLS AND PIEZOMETERS IN SCHEMATIC AT LEFT ARE FOR ILLUSTRATION ONLY.
4. SUBSURFACE PROFILE IS BASED UPON DRILLING RECORDS AND IS GENERALIZED.

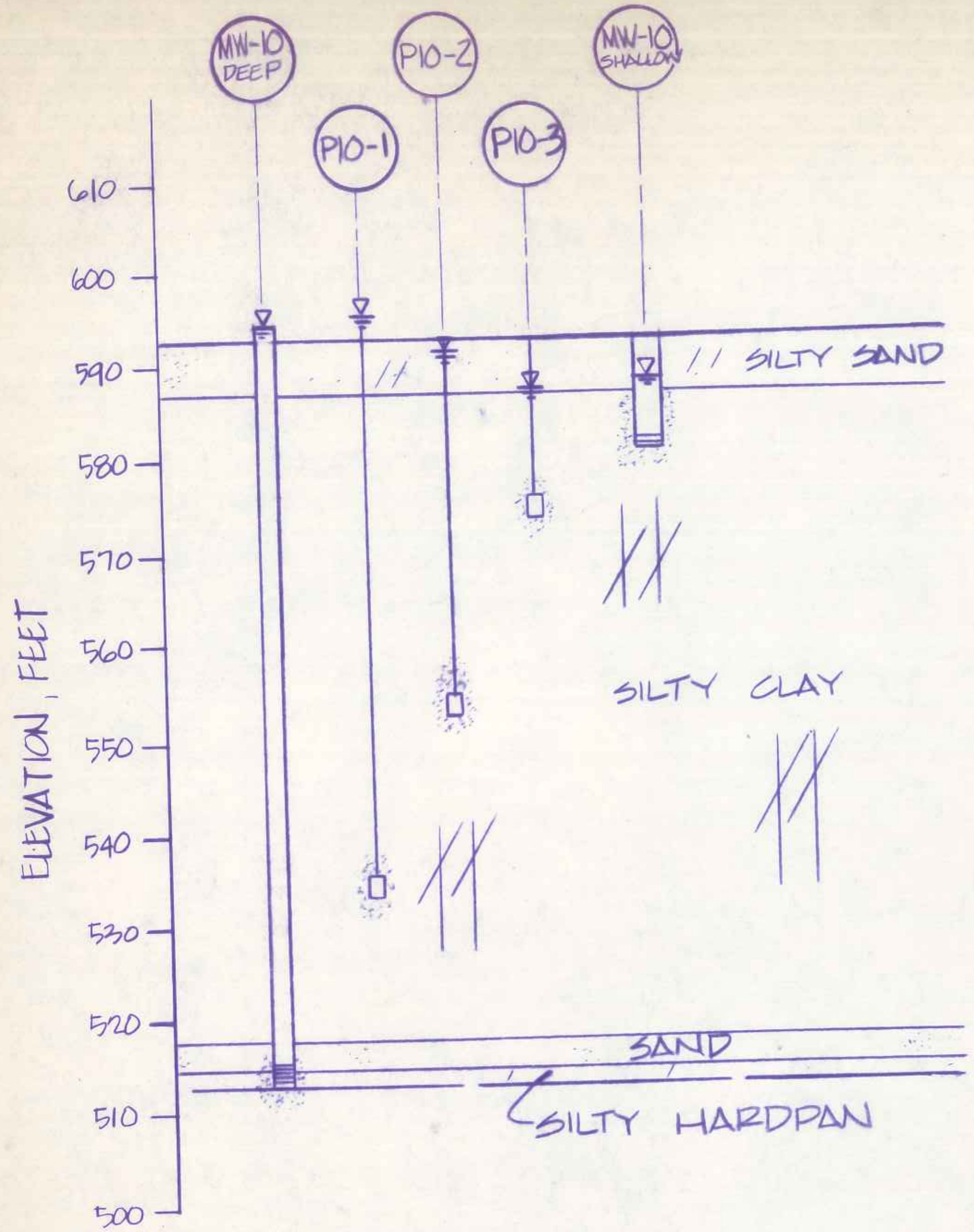
PIEZOMETRIC DATA ILLUSTRATION, NEST No. 5

ALLEN PARK CLAY MINE LANDFILL
FORD MOTOR COMPANY
ALLEN PARK, MICHIGAN

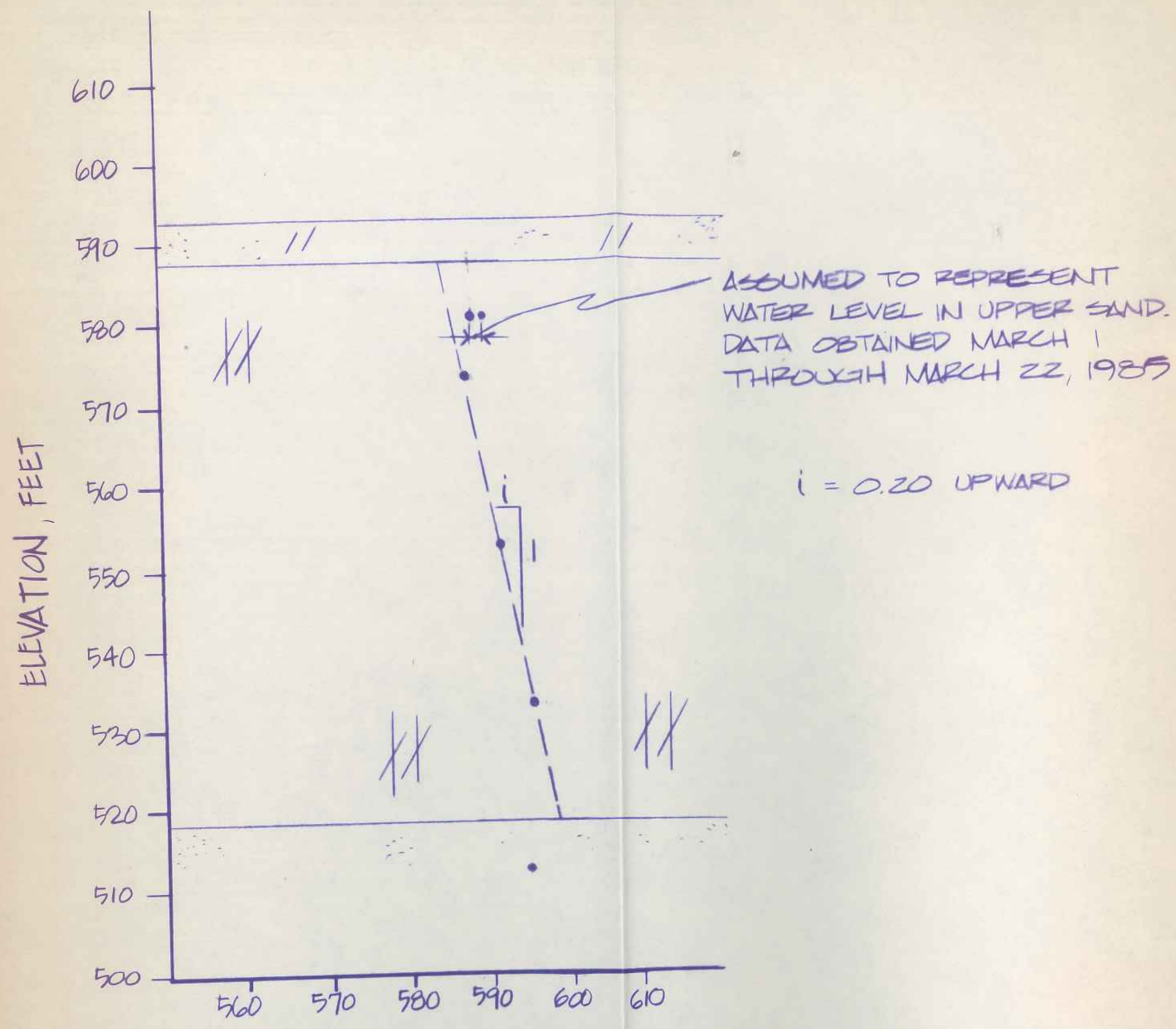
NTH NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD. · FARMINGTON HILLS, MI 48024

PROJECT NO.: 84185	DRAWN BY: JFK	DATE: 3-28-85
SCALE: NONE	CHECKED BY: WRB	SHEET 1 OF 1

PLATE 3



SCHEMATIC OF PIEZOMETRIC DATA



PIEZOMETRIC (WATER LEVEL) ELEVATION, FEET

NOTES:

1. PIEZOMETRIC DATA OBTAINED BY NEYER, TISEO & HINDO, LTD. ON MARCH 22, 1985.
2. PIEZOMETERS (DENOTED BY "P") WERE INSTALLED BY NEYER, TISEO & HINDO, LTD. WELLS WERE INSTALLED BY OTHERS.
3. HORIZONTAL POSITIONS OF WELLS AND PIEZOMETERS IN SCHEMATIC AT LEFT ARE FOR ILLUSTRATION ONLY.
4. SUBSURFACE PROFILE IS BASED UPON DRILLING RECORDS AND IS GENERALIZED.

PIEZOMETRIC DATA ILLUSTRATION, NEST No. 10

ALLEN PARK CLAY MINE LANDFILL
FORD MOTOR COMPANY
ALLEN PARK, MICHIGAN

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD. · FARMINGTON HILLS, MI 48024

PROJECT NO.: 84185	DRAWN BY: JFK	DATE: 3-28-85
SCALE: NONE	CHECKED BY: WRB	SHEET 1 OF 1

PLATE 4

N56017

NEYER, TISEO & HINDO, LTD.

GENERAL NOTES

TERMINOLOGY

Unless otherwise noted, all terms utilized herein refer to the Standard Definitions presented in ASTM D 653.

PARTICLE SIZES

Boulders	-	Greater than 12 inches (305mm)
Cobbles	-	3 inches (76.2mm) to 12 inches (305mm)
Gravel - Coarse	-	3/4 inches (19.05mm) to 3 inches (76.2mm)
Fine	-	No. 4 - 3/16 inches (4.75mm) to 3/4 inches (19.05mm)
Sand Coarse	-	No. 10 (2.00mm) to No. 4 (4.75mm)
Medium	-	No. 40 (0.425mm) to No. 10 (2.00mm)
Fine	-	No. 200 (0.074mm) to No. 40 (0.425mm)
Silt	-	0.005mm to 0.074mm
Clay	-	Less than 0.005mm

COHESIONLESS SOILS

Classification

The major soil constituent is the principal noun, i.e. sand, silt, gravel. The second major soil constituent and other minor constituents are reported as follows:

Second Major Constituent (percent by weight)	Minor Constituents (percent by weight)
Trace - 1 to 12%	Trace - 1 to 12%
Adjective - 12 to 35% (clayey, silty, etc.)	Little - 12 to 23%
And - Over 35%	Some - 23 to 33%

Density Classification	Relative Density %	Approximate Range of (N)
Very Loose	0-15	0-4
Loose	16-35	5-10
Medium Compact	36-65	11-30
Compact	66-85	31-50
Very Compact	86-100	Over 50

Relative Density of Cohesionless Soils is based upon the evaluation of the Standard Penetration Resistance (N), modified as required for depth effects, sampling effects, etc.

COHESIVE SOILS

If clay content is sufficient so that clay dominates soil properties, clay becomes the principal noun with the other major soil constituent as modifier; i.e., silty clay. Other minor soil constituents may be included in accordance with the classification breakdown for cohensionless soils; i.e., silty clay, trace of sand, little gravel.

Consistency	Unconfined Compressive Strength (psf)	Appromixate Range of (N)
Very Soft	Below 500	0-2
Soft	500-1000	3-4
Medium	1000-2000	5-8
Stiff	2000-4000	9-15
Very Stiff	4000-8000	16-30
Hard	8000-16000	31-50
Very Hard	Over 16000	Over 50

Consistency of cohesive soils is based upon an evaluation of the observed resistance to deformation under load and not upon the Standard Penetration Resistance (N).

SAMPLE DESIGNATIONS

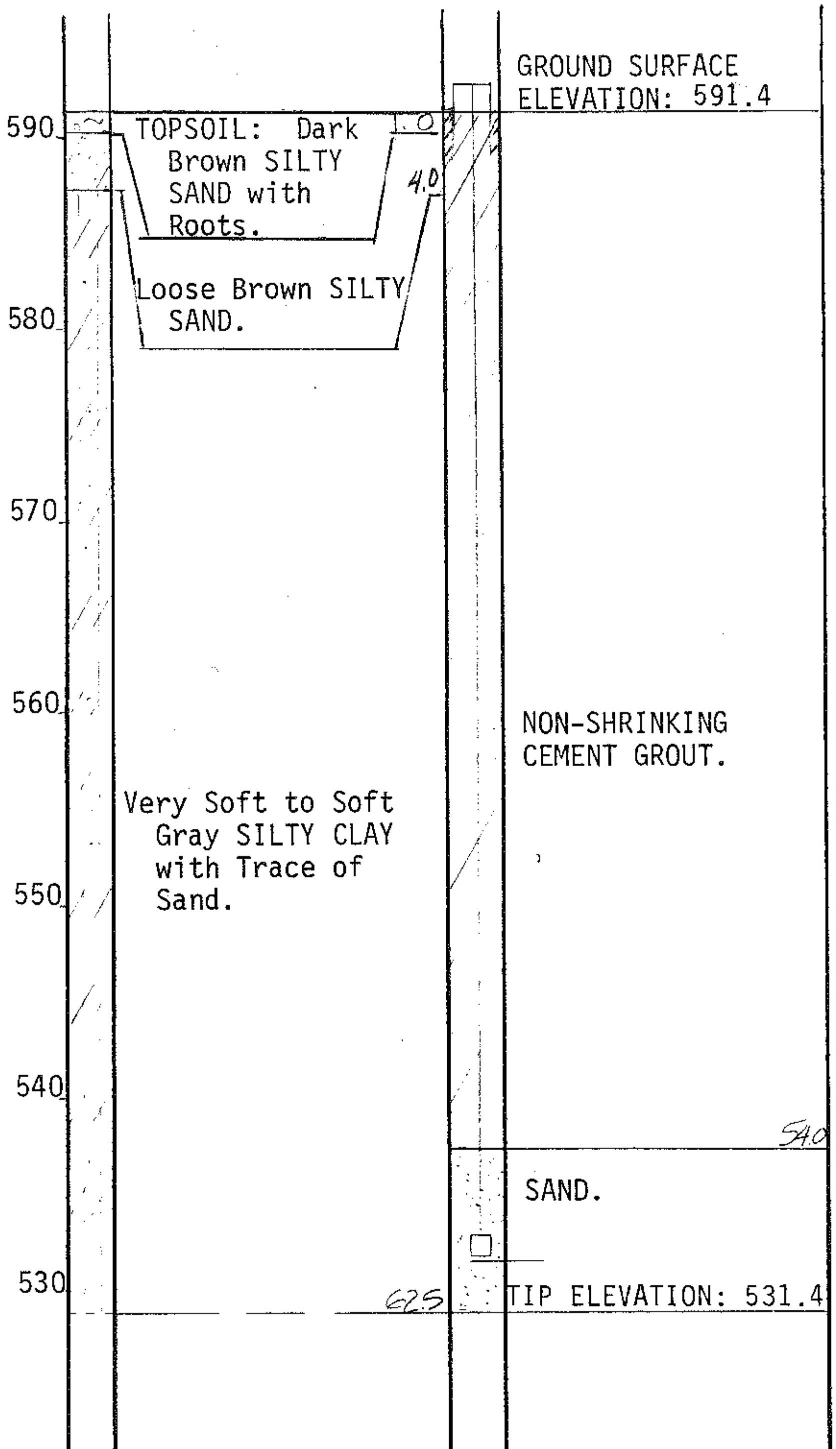
AS - Auger Sample - Directly from auger flight.
BS - Miscellaneous Samples - Bottle or Bag.
S - Split Spoon Sample with Liner Insert - ASTM D 1586
LS - Liner Sample S with liner insert 3 inches in length.
ST - Shelby Tube Sample - 3 inch diameter unless otherwise noted.
PS - Piston Sample - 3 inch diameter unless otherwise noted.
RC - Rock Core - NX core unless otherwise noted.

STANDARD PENETRATION TEST (ASTM D 1586) - A 2.0" outside-diameter, 1-3/8" inside-diameter split barrel sampler is driven into undisturbed soil by means of a 140-pound weight falling freely through a vertical distance of 30 inches. The sampler is normally driven three successive 6-inch increments. The total number of blows required for the final 12 inches of penetration is the Standard Penetration Resistance (N).

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE	SCHEMATIC



NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 60.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 2.5 ft, 5.0 ft and 62.5 ft.

GROUNDWATER DATA

DATE	PIEZO-METRIC ELEV. (FEET)	COMMENTS
2-20-85	578.2	
2-21-85	589.6	
3-01-85	593.7	
3-08-85	594.4	
3-11-85	595.1	
3-22-85	595.3	

STARTED: 2-19-85
COMPLETED: 2-19-85
INSPECTOR: A. Al-Saati
DRILLER: D. Klitz
CONTRACTOR: West Michigan Drilling
EQUIPMENT: Trailer mounted CME-55
PIEZOMETER TYPE: Pneumatic operated SINCO Model No. 514178

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD., FARMINGTON HILLS, MI 48024

PIEZOMETER NO. 2-1

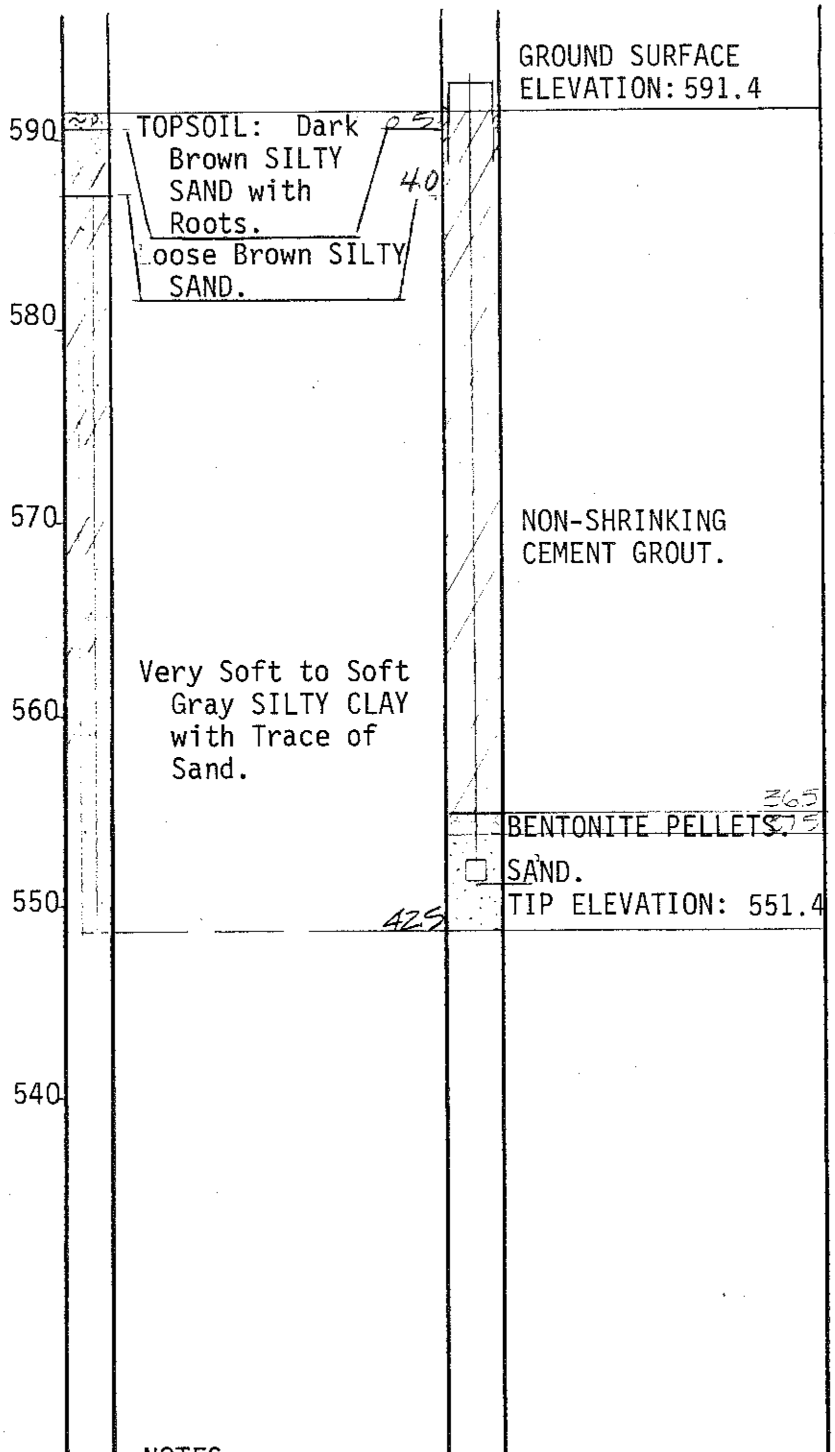
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-8-85
PROJECT NO: 84185 OW	FIGURE NO: 1

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE	SCHEMATIC



NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 40.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 2.5 ft., 5.0 ft. and 42.5 ft.

GROUNDWATER DATA

DATE	PIEZOMETRIC ELEV. (FEET)	COMMENTS
2-20-85	586.9	
2-21-85	588.3	
3-01-85	591.0	
3-08-85	591.0	
3-11-85	590.7	
3-22-85	591.0	

STARTED: 2-19-85
COMPLETED: 2-19-85
INSPECTOR: A. Al-Saati
DRILLER: D. Klitz
CONTRACTOR: West Michigan Drilling
EQUIPMENT: Trailer mounted CME-55
PIEZOMETER TYPE: Pneumatic operated SINCO Model No. 514178

NOTES - Continued

5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD., FARMINGTON HILLS, MI 48024

PIEZOMETER NO. 2-2

ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-8-85
PROJECT NO: 84185 OW	FIGURE NO: 2

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

ELEVATION - FEET	GENERALIZED SUBSURFACE PROFILE	SCHEMATIC
		GROUND SURFACE ELEVATION: 591.5
590	TOPSOIL: Dark Brown SILTY SAND with Roots. (1.5) (4.0)	
	Loose Brown SILTY SAND.	
580		NON-SHRINKING CEMENT GROUT.
	Soft Gray SILTY CLAY with Trace of SAND.	17.0
570	22.5	SAND. TIP ELEVATION: 571.5
560		

NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 20.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 5.0 ft. and 22.5 ft.

GROUNDWATER DATA

DATE	PIEZO-METRIC ELEV. (FEET)	COMMENTS
2-21-85	583.3	
3-01-85	585.5	
3-08-85	585.8	
3-11-85	586.5	
3-22-85	586.7	

STARTED: 2-20-85
COMPLETED: 2-20-85
INSPECTOR: A. Al-Saati
DRILLER: D. Klitz
CONTRACTOR: West Michigan Drilling
EQUIPMENT: Trailer mounted CME-55
PIEZOMETER TYPE: Pneumatic operated SINCO Model No. 514178

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 TEN MILE RD., FARMINGTON HILLS, MI 48024

PIEZOMETER NO. 2-3

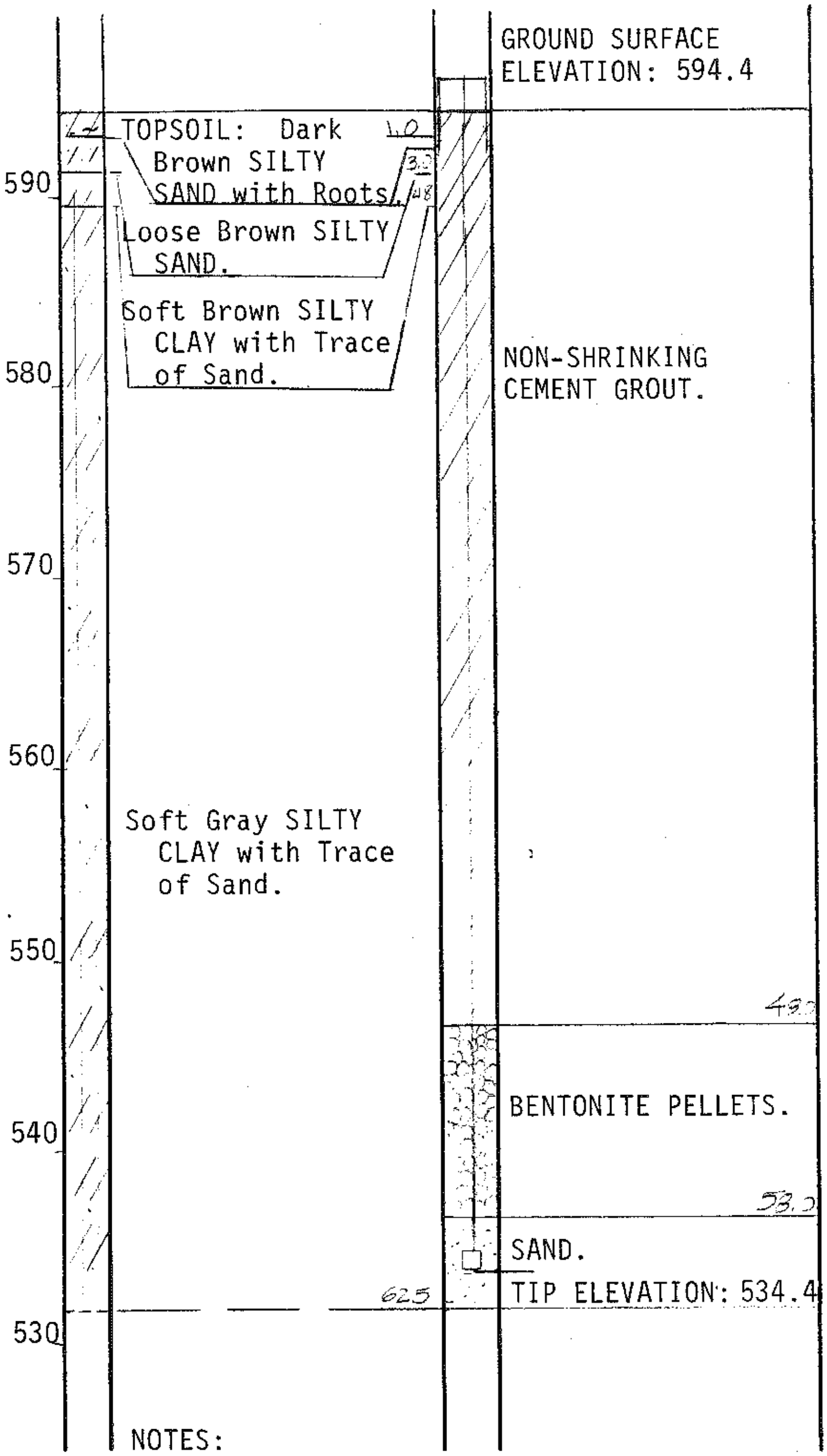
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LTS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 3

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE | SCHEMATIC



GROUNDWATER DATA

DATE	PIEZOMETRIC ELEV. (FEET)	COMMENTS
2-15-85	548.2	
2-18-85	563.4	
2-19-85	568.9	
2-20-85	573.3	
2-21-85	575.9	
2-28-85	587.4	
3-01-85	589.1	
3-08-85	592.5	
3-11-85	594.1	
3-22-85	596.3	

STARTED:	2-13-85
COMPLETED:	2-13-85
INSPECTOR:	L. J. Shekter
DRILLER:	D. Klitz
CONTRACTOR:	West Michigan Drilling
EQUIPMENT:	Trailer mounted CME-55
PIEZOMETER TYPE:	Pneumatic operated SINCO Model No. 514178

NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 61.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 2.5 ft., 5.0 ft. and 62.5 ft.

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
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PIEZOMETER NO. 5-1

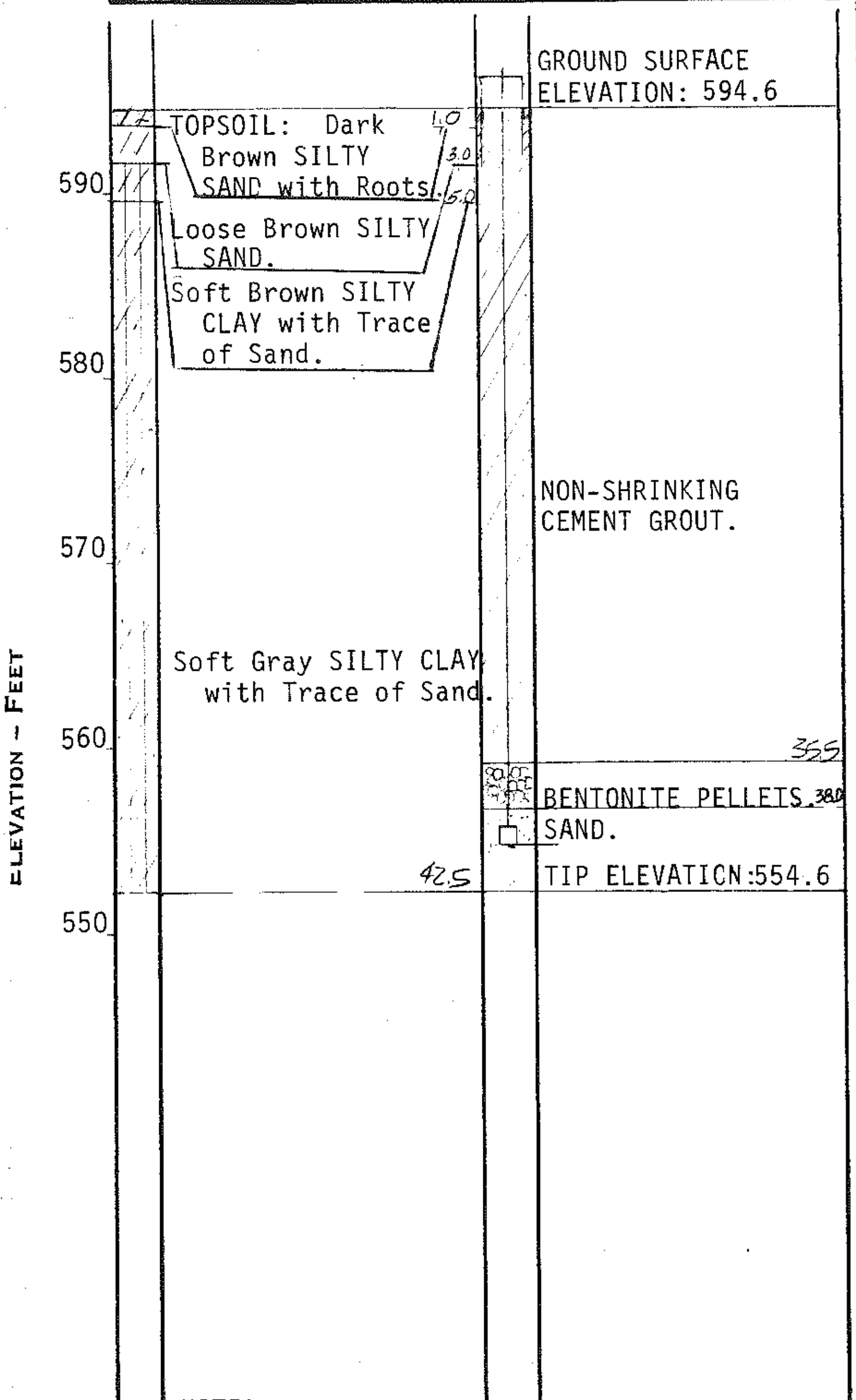
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 4

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE	SCHEMATIC



GROUNDWATER DATA

DATE	PIEZO-METRIC ELEV. (FEET)	COMMENTS
2-15-85	580.0	
2-18-85	584.1	
2-19-85	584.6	
2-20-85	586.9	
2-21-85	586.9	
2-28-85	589.3	
3-01-85	590.5	
3-08-85	590.2	
3-11-85	590.9	
3-22-85	593.2	

STARTED:	2-14-85
COMPLETED:	2-14-85
INSPECTOR:	L.J. Shekter
DRILLER:	D. Klitz
CONTRACTOR:	West Michigan Drilling
EQUIPMENT:	Trailer mounted CME-55
PIEZOMETER TYPE:	Pneumatic operated SINCO Model No. 514178

NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 40.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 2.5 ft., 5.0 ft. and 42.5 ft.

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
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30999 TEN MILE RD., FARMINGTON HILLS, MI 48024

PIEZOMETER NO. 5-2

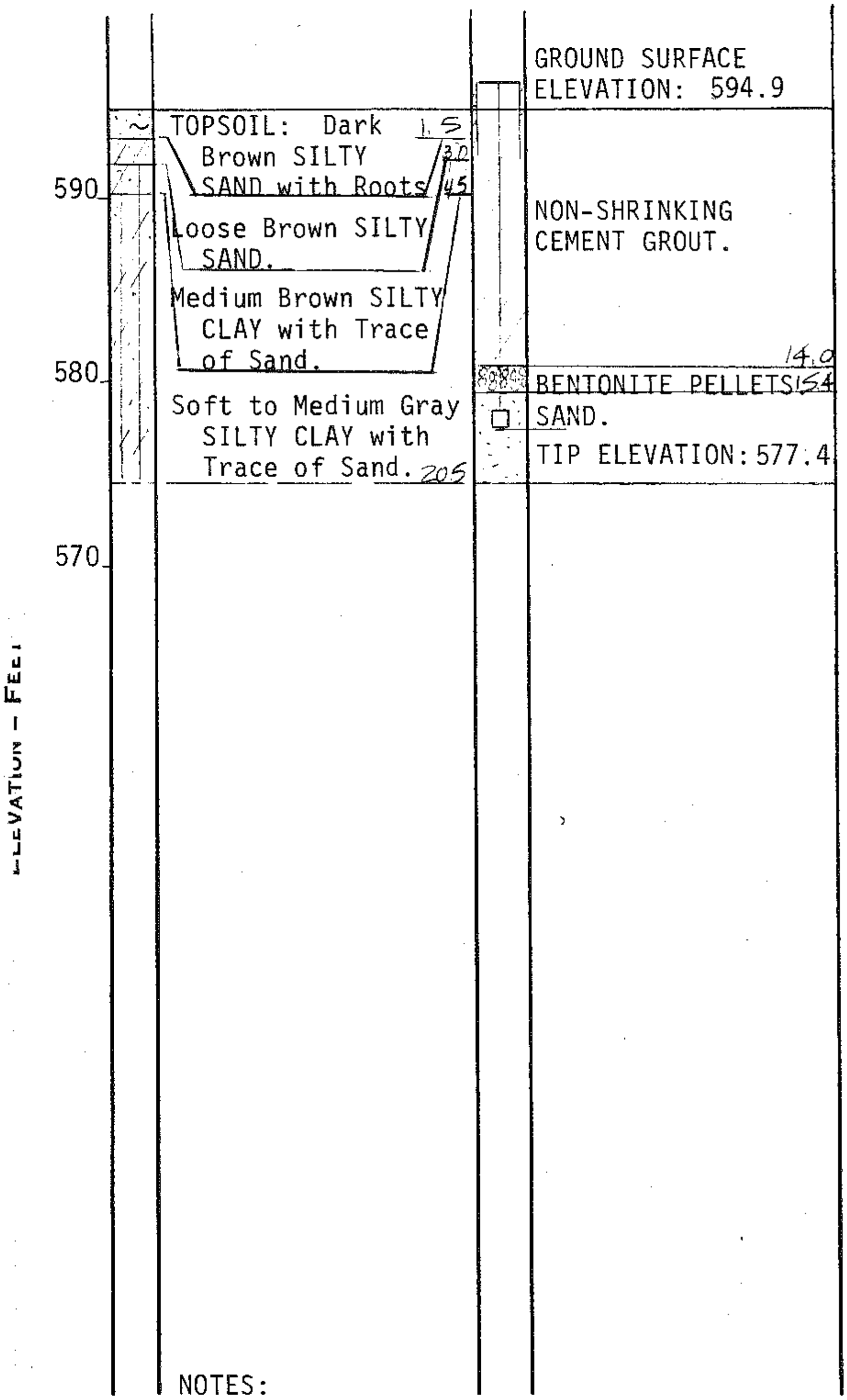
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 5

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE	SCHEMATIC



NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 17.5 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 2.5 ft., 5.0 ft. and 20.5 ft.

GROUNDWATER DATA

DATE	PIEZO-METRIC ELEV. (FEET)	COMMENTS
2-15-85	587.1	
2-18-85	590.5	
2-19-85	592.9	
2-20-85	591.2	
2-21-85	591.2	
3-01-85	591.7	
3-08-85	592.4	
3-11-85	591.9	
3-22-85	591.7	

STARTED: 2-15-85
COMPLETED: 2-15-85
INSPECTOR: L. J. Shekter
DRILLER: D. Klitz
CONTRACTOR: West Michigan Drilling
EQUIPMENT: Trailer mounted CME-55
PIEZOMETER TYPE: Pneumatic operated SINCO Model No. 514178

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
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PIEZOMETER No. 5-3

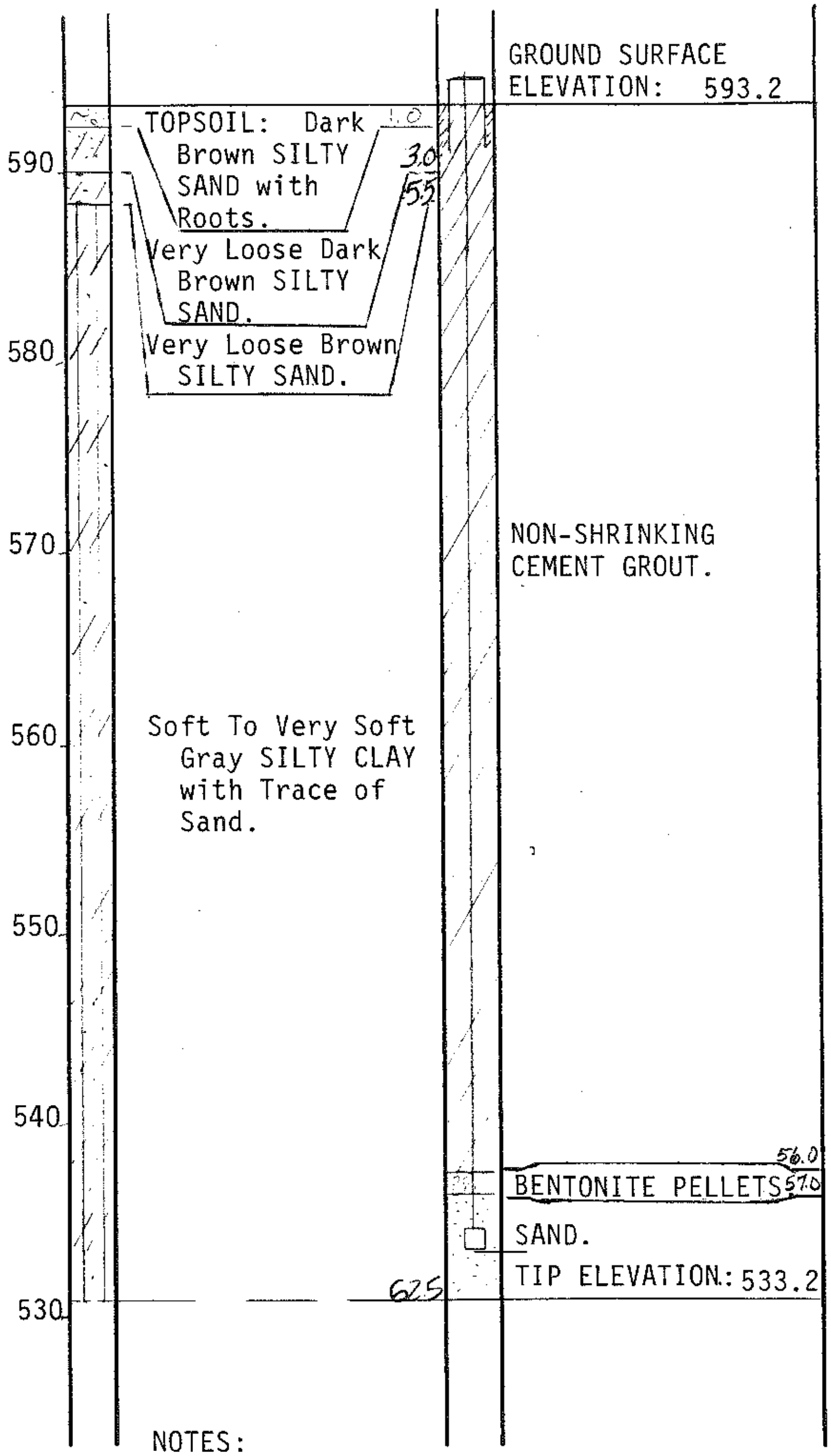
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 6

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE	SCHEMATIC



GROUNDWATER DATA

DATE	PIEZO-METRIC ELEV. (FEET)	COMMENTS
2-19-85	541.5	
2-20-85	554.0	
2-21-85	565.5	
3-01-85	594.2	
3-08-85	595.1	
3-11-85	595.3	
3-22-85	595.5	

STARTED: 2-18-85
COMPLETED: 2-18-85
INSPECTOR: A. Al-Saati
DRILLER: D. Klitz
CONTRACTOR: West Michigan Drilling
EQUIPMENT: Trailer mounted CME-55
PIEZOMETER TYPE: Pneumatic operated SINCO Model No. 514178

NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 60.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 2.5 ft., 5.0 ft., 7.5 ft. and 62.5 ft.

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
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PIEZOMETER NO. 10-I

ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

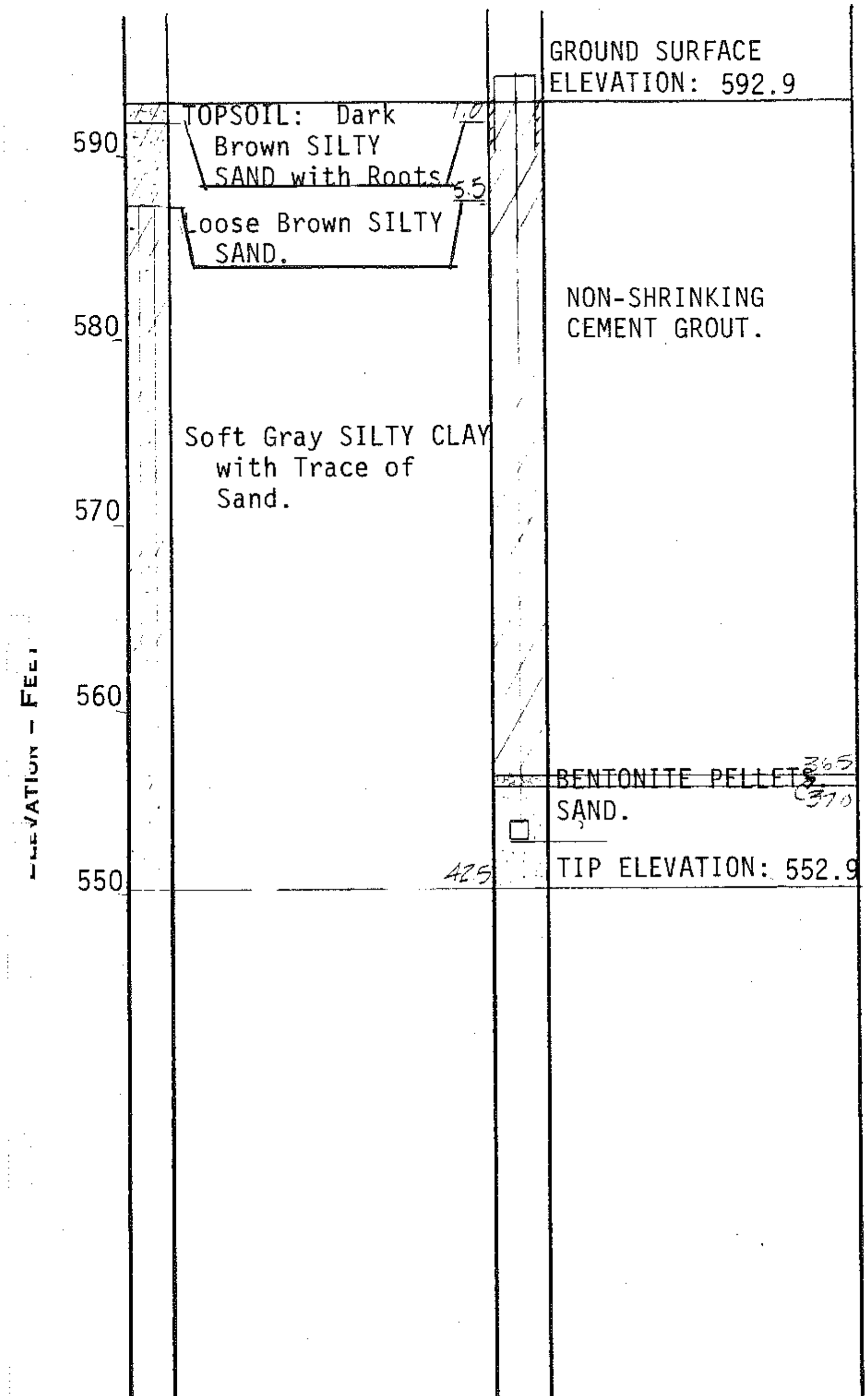
APPROVED BY: LTS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 7

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:

NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE | SCHEMATIC



GROUNDWATER DATA

DATE	PIEZO-METRIC ELEV. (FEET)	COMMENTS
2-19-85	589.4	
2-20-85	590.3	
2-21-85	590.3	
3-01-85	590.2	
3-08-85	591.1	
3-11-85	591.1	
3-22-85	591.1	

STARTED:	2-18-85
COMPLETED:	2-18-85
INSPECTOR:	A. Al-Saati
DRILLER:	D. Klitz
CONTRACTOR:	West Michigan Drilling
EQUIPMENT:	Trailer mounted CME-55
PIEZOMETER TYPE:	Pneumatic operated SINCO Model No. 514178

NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 40.0 feet below the ground surface.
3. Drilling utilized 8-inch diamter hollow-stem augers.
4. Samples were recovered from depths of 5.0 ft., 7.5 ft. and 42.5 ft.

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
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PIEZOMETER No. 10-2

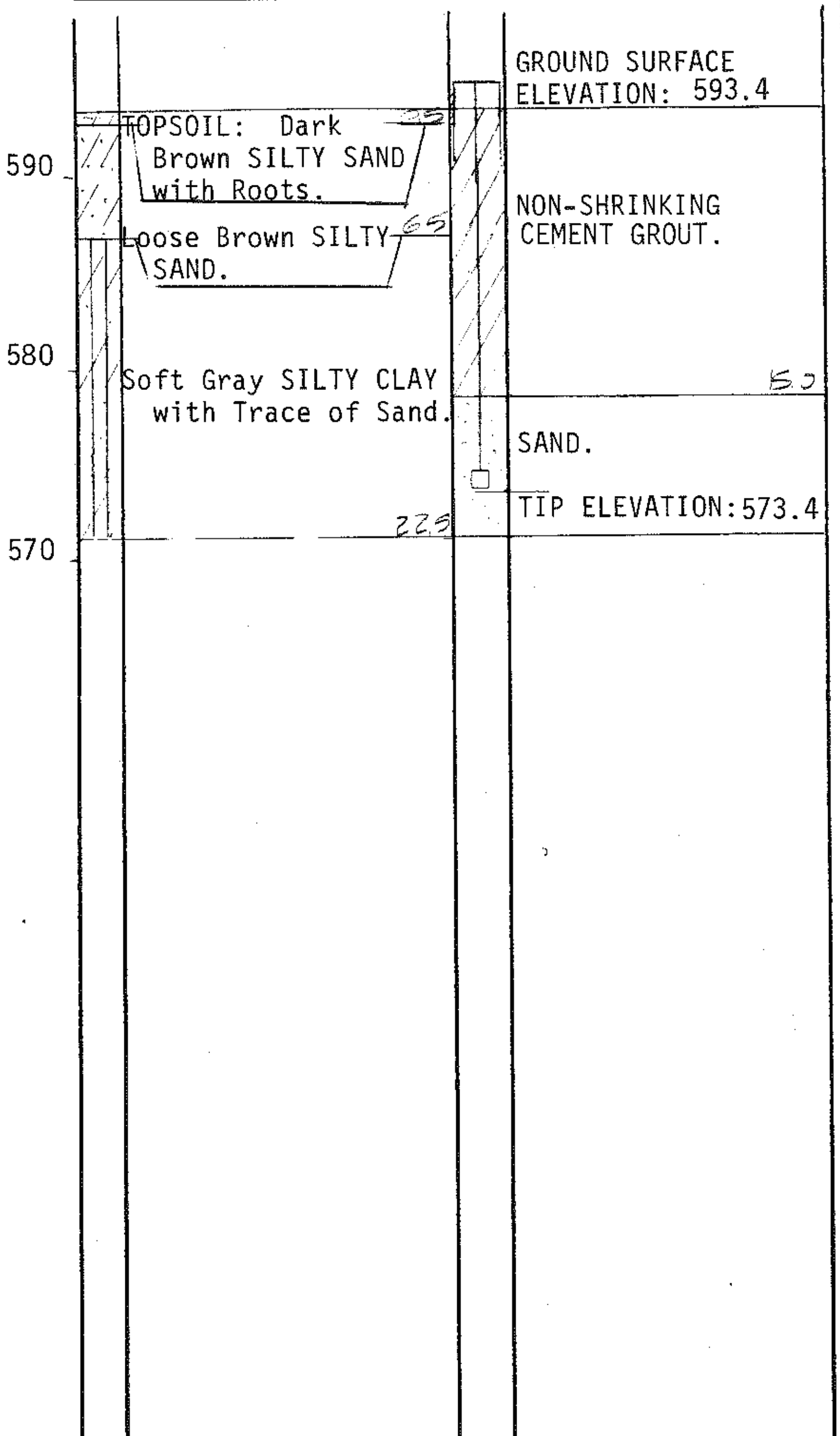
ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 8

LOG OF PIEZOMETER INSTALLATION

CLASSIFICATIONS BY:
NEYER, TISEO & HINDO, LTD.

GENERALIZED SUBSURFACE PROFILE	SCHEMATIC



NOTES:
1. Piezometer leads protected by 4 foot length, 5-inch diameter, Sch 40 PVC casing at the ground surface.
2. Piezometer tip set at 20.0 feet below the ground surface.
3. Drilling utilized 8-inch diameter hollow-stem augers.
4. Samples were recovered from depths of 5.0 ft, 7.5 ft. and 22.5 ft.

GROUNDWATER DATA

DATE	PIEZOMETRIC ELEV. (FEET)	COMMENTS
2-20-85	582.2	
2-21-85	583.6	
3-01-85	587.0	
3-08-85	587.0	
3-11-85	587.4	
3-22-85	587.4	

STARTED:	2-19-85
COMPLETED:	2-19-85
INSPECTOR:	A. Al-Saati
DRILLER:	D. Klitz
CONTRACTOR:	West Michigan Drilling
EQUIPMENT:	Trailer mounted CME-55
PIEZOMETER TYPE:	Pneumatic operated SINCO Model No. 514178

NOTES - Continued
5. Soil descriptions were based upon visual identification of the auger spoil as well as the limited number of samples noted above.

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
38955 TEN MILE RD., FARMINGTON HILLS, MI 48024

PIEZOMETER NO. 10-3

ALLEN PARK CLAY MINE LANDFILL
ALLEN PARK, MICHIGAN

APPROVED BY: LJS	DATE: 3-11-85
PROJECT NO: 84185 OW	FIGURE NO: 9

NEYER, TISEO & HINDO, LTD.
CONSULTING ENGINEERS
30999 Ten Mile Road • Farmington Hills, MI 48024 • (313) 471-0750
2053 South Dort Highway • Flint, MI 48503 • (313) 232-9652
2615 Comerica Building • Detroit, MI 48226 • (313) 965-0036

EXHIBIT I

JOB Allen Park Clay Mine PROJECT NO. 84185 SHEET NO. 2/13
SUBJECT Leachate Collection System BY WRB DATE 5/30/84
CHK. BY LJS DATE 6/28/84

Alternative Water Balance - Intermediate Cover

Assume 40% of precipitation evaporates each year (Fenn, et al., 1975) because of bare soil - no vegetation to assist evapotranspiration.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	53	54	62	68	85	84	79	71	68	63	59	57	803 mm
C_{SRO}	0.3	.3	.3	.28	.27	.25	.2	.2	.25	.27	.28	.3	
SRO	16	16	19	19	23	21	16	14	17	17	17	17	212
	37	38	43			63							
Evap.	21	22	25	27	34	34	32	28	27	25	24	23	322
PERC	16	16	18	22	28	29	31	29	24	21	18	17	269 mm

Max. rate (percolation) $\approx 31\,mm/31\,days = 1\,mm/day$

Max rate from previous water balance $= 38\,mm/28\,days = 1.36\,mm/day$

Use $FS = 1.5 \rightarrow q_{design} = 1.5 \times 1.36 = 2.0\,mm/day$

$$q_{design} = 2.0\,mm/day \left(\frac{cm}{10\,mm}\right)\left(\frac{day}{24\,hr}\right)\left(\frac{hr}{3600\,sec}\right) = 2.3 \times 10^{-6}\,cm/sec$$

2.36

Check upward flow from aquifer into cell -

$$K_{ave} \approx 2.6 \times 10^{-8}\,cm/sec \quad i \approx \frac{604-555}{555-521} = 1.4$$

$$q_{upward} \approx 2.6 \times 10^{-8}\,cm/sec\,(1.4) = 3.7 \times 10^{-8}\,cm/sec$$

This is less than 2% of $q_{design} \rightarrow$ Negligible

TO: Ken Burda / ~~Gerry McNiel~~
HWD - Permits

FROM: Larry ... Buchan
HWD

Page 1 of 2

SUBJECT: FMC Allen Park Clay Mine Landfill

OUR JOB NO.

DATE OF MEMO 10/9/84

MESSAGE

I would request your expeditious review and approval of the subject facility's leachate collection system in Cell 1 as indicated in their submitted plans.

The following stipulations/modifications should be considered:

1. The approval is only granted for this particular manhole and leachate system within these plans.
2. Approval should not address the leachate removal system (ie pumps, discharge line, electrical)

SENDER – DO NOT WRITE BELOW THIS LINE

SIGNED

REPLY

3. The leachate pipe installation is the trench method
4. The separation dike should be constructed using the same (See Item 5a - FMC 9/17/84) specifications as the Wayne Disposal separation dikes.
5. The Department must be notified 48 hours prior to commencing the leachate system construction.
6. Certification of this work must be made in accordance with Specific Condition 21 of the facility's operating license. See page 2.

SIGNED

DATE

ORIGINAL

SENDER — Retain part 2 for your follow-up, send parts 1 and 3 to addressee
RECIPIENT — Retain part 1 and return part 3

TO:	FROM:
Ken Buida / Terry McNiel HWD Permits	Larry [illegible]

SUBJECT:	OUR JOB NO.	DATE OF MEMO
FMC APCM Landfill		10/9/84

MESSAGE

7. Please consider point 5 in FMC September 17, 1984 letter for possible refinements and inclusion in the approval especially the testing procedures in 5b.

Thanks

SIGNED Larry

SENDER — DO NOT WRITE BELOW THIS LINE

REPLY

SIGNED DATE

ORIGINAL

SENDER — Retain part 2 for your follow-up, send parts 1 and 3 to addressee
RECIPIENT — Retain part 1 and return part 3

Steel Division
Ford Motor Company

P.O. Box 1639
Dearborn, Michigan 48121

September 17, 1984

Mr. Larry AuBuchon
Hazardous Waste Division
Michigan Department of Natural Resources
15500 Sheldon Road
Northville, Michigan 48167

Subject: Ford Allen Park Clay Mine
EPA I.D. No. MID 980568711

Reference: Your August 8, 1984 letter to me

Dear Mr. AuBuchon:

This is in response to the above-referenced letter in which you offered several comments regarding operations at the subject facility, as well as requested specific supplemental information relevant to placement of the proposed leachate collection piping system.

With respect to the proposed leachate collection system for Hazardous Waste Cell I, the enclosed drawings dated 4/23/84 and 6/27/84 provide for our proposed revisions to the subject facility's leachate collection system. These plans supersede design plans dated 4/20/82 which are presently incorporated into the facility's Michigan Act 64 operating license. The detailed item included in the proposed revisions is the utilization of the trench method for the leachate collection pipe. This responds to item 3 in your August 8, 1984 letter.

The remaining comments referred to in your letter appear to us to lack the requisite regulatory basis and should not bear on resolution of the leachate collection system issue. To the extent that your comments can forthrightly be addressed by this communication, I will attempt to do so in the expectation that your concerns can be allayed consistent with applicable Act 64 and RCRA regulations.

1. Comment - "Request all below ground concrete be coated on all sides."

   Response - Proposed design plans for the base of the concrete collection sump specify an epoxy coating on both sides to prevent exposure of the concrete to the leachate. The additional concrete risers will not have prolonged exposure to the leachate, and therefore, design plans do not specify that they be coated with epoxy, in accordance with good engineering design practice.

2. Comment - "Insure that run-on/run-off requirements contained in 40 CFR 265.302 are addressed with supporting documentation."

   Response - Since the disposal cell is an excavation, the run-off is controlled by collection in the bottom of the cell. Topography adjacent to the cell provides for only one possible access area for run-on which is on the southwest side of the cell. This area presently maintains a dike barrier (3 feet high) designed to hold the accumulation from a 24 hour, 25 year storm.

3. Comment - "The pipe strength calculations were prepared for trench method installation, however, the plans do not indicate utilization of the trench method."

   Response - The enclosed drawings provide for the trench method.

4. Comment - "Address how the pump system, including the discharge hose, will be operated/maintained during freezing operations."

   Response - The elevations of the discharge line provide for a gravity drain so that standing water does not remain in the line.

5. Comment - "The program which will be implemented to address the following must be clarified:

   a) Isolation of Cell I to maintain a separation of the contaminated/uncontaminated run-off. (Include construction detail and specifications.)

   b) Removal of the contaminated soil from the future "uncontaminated" side of Cell I including proposed test verification.

   c) Capping procedure on the west slope and top of the previously filled area."

5. Response - a) The unfilled (west) portion of Cell I will be separated from the active filled (east) portion of the cell by the installation of a clay dike barrier. The dike will slope. A small bulldozer will cut the key the width of the blade and two feet deep. Dike material shall have a unified soil classification of CL or CH as determined by ASTM standard D2487-69, placed in horizontal lifts not to exceed one foot and shall be compacted to not less than 80% of the maximum dry density as determined by the modified proctor test described in ASTM standard D1557-40. The dike will extend 3 feet above the toe of the slope and will be tied into the cover.

b) The contaminated soil will be scraped by bulldozer from the unfilled (west) portion of the cell and placed over the filled (east) portion of the cell. Depth of soil removal will be approximately 6 inches. Proposed test verification of the clean soil would be EP toxicity tests of composite soil samples, each of which is representative of approximately 10,000 square feet.

c) Capping procedure of the filled (east) portion of the cell will be as follows:

1) Material will have a unified soil classification of CL or CH as determined by ASTM D2487-69.

2) Placed in a thickness greater than six inches.

3) Compacted to not less than 80% of the maximum dry density as per ASTM D1557-40.

To enable installation of the collection system during the limited remaining 1984 construction season, we respectfully request that you expedite the required Director's approval for the proposed revisions to the original plans.

Yours very truly,

Ben C. Trethewey

Ben C. Trethewey, Manager
Mining Properties Department

Enclosures

bcc: Messrs. J. A. Esper
G. Kircos
V. H. Sussman
S. H. Vaughn

Terry
See if they will respond
CWK

~~Dist~~
~~KE~~ Ben, Al

XL : KEN

THIS COPY: CHUCK.

Chuck,
please have Terry discuss w/ Larry. Someone shld prepare response. I'd like to see a copy
Al 7/11

Ford Motor Company

3001 Miller Road
Dearborn, Michigan 48121

July 2, 1984

Mr. Larry AuBuchon
Department of Natural Resources
Environmental Protection Bureau
1120 West State Fair Avenue
Detroit, Michigan 48203

Subject: Ford Allen Park Clay Mine
MID 980568711

Dear Mr. AuBuchon:

This submittal addresses the issues raised in Mr. Terry McNiel's memorandum dated June 6, 1984, which you provided to this office in your June 15, 1984 letter.

1. Concern - "Possible lateral movement of groundwater through the clay stratum might allow leachate to migrate through the liner sidewalls."

   Response - The aquifer has been identified as a stratum parallel to the ground surface. Under uniform confining pressure (clay stratum overlying aquifer), the hydraulic gradient vector of the aquifer (and the water saturating the confining clay stratum) is normal to both the aquifer and the ground surface.

   With the excavation of the disposal cell, the uniform confining pressure is locally disturbed, and the hydraulic gradient vectors become noral to the disposal cell walls. This creates a localized zone of influence which results in groundwater movement into the cell as opposed to lateral movement out of the cell. Therefore, there will be no lateral movement of leachate or groundwater out of the cell under these geological conditions.

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JUL 05 1984
HAZARDOUS WASTE DIVISION

2. Concern - "Containment times cannot be estimated unless the clay's hydraulic conductivity when exposed to the leachate generated is known."

Response - Containment times have been provided by Professor Donald H. Gray in previous submittals. The concern of leachate increasing permeabilities of the clay liner is addressed in his February 16, 1984 correspondence as follows:

"I showed that even under worst case assumptions of no partitioning or attenuation of pollutants and minimum, negative hydraulic gradients breakthrough times would be on the order of thousands of years. Interestingly, if the calculations are repeated allowing hydraulic conductivity or permeability to double or even triple, the breakthrough time increases even more because now the counter advective flow is more effective in opposing the downward diffusion of solutes along their concentration gradient."

3. Concern - "It is still not clear which direction the confined aquifer flows (poor well construction) or whether there is an upward gradient (no piezometer nests) at trench bottom."

Response - The hydrogeologic report prepared by Michigan Testing Engineers, Inc. has defined the flow direction of the aquifer (southeast) and that there is an upward gradient. We are in agreement with both of these conclusions, despite unsubstantiated MDNR concerns to the contrary. If there is evidence contrary to these conclusions, it should be presented. We agree with Michigan Testing Engineers, Inc. that piezometer nests are not necessary to determine that there is an upward gradient at the site. In addition, we agree that the monitor wells were properly constructed in view of the regional trend of groundwater flow.

As you are well aware, there has been much debate over these issues both since, and prior to, permit issuance on October 22, 1982. We believe that all required MDNR regulatory and permit standards have been met. If MDNR management feels that this is not the case, we and our technical consultants, are available to meet with Messrs. Howard or Rector of the Hazardous Waste Division at their convenience to finally resolve this matter.

Yours very truly,

Ben C. Trethewey

Ben C. Trethewey, Manager
Mining Properties Department

cc: Mr. Delbert Rector

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

INTEROFFICE COMMUNICATION

June 6, 1984

TO: Larry Aubuchon, Detroit District, Hazardous Waste Division

FROM: Terry McNiel, Technical Services Section, Hazardous Waste Division

SUBJECT: Ford Motor Company Allen Park Clay Mine

I have reviewed Ford's May 10, 1984 submittal and have the following comments:

Specific Condition 5.A.4(a): There appears to be some confusion as to this Department's concerns as the containment ability of this facility. These concerns have been communicated to Mr. David Miller and are reiterated here.

A leak detection system serves to give an early warning of contaminant release down through the liner at a typical site with a non-confined aquifer. With a potentiometric surface above trench bottom, flow is not expected to be down through the liner but upward and/or laterally. Ford is failing to consider this avenue of movement, and cites the artesian conditions as precluding this movement out of the disposal cell. These conditions only lead to the assumption of no movement through the bottom of the cell. Containment times cannot be estimated unless the clay's hydraulic conductivity when exposed to the leachate generated is known. There are concerns as to the interconnection of the artesian aquifer and the water table aquifer. The water table aquifer's isolation from the Allen Drain is also questionable due to lack of details on the dike construction and certification on the east side of Cell Number 1. Non-saturated conditions at the elevation of trench bottom will provide an opportunity for contaminants to move down and then laterally. It is still not clear which direction the confined aquifer flows (poor well construction) or whether there is an upward gradient (no piezometer nests) at trench bottom. This demonstration has yet to be finalized.

The above scenerio is a worst case situation. However, Ford is looking at the "best case" situation. When dealing with toxic chemicals, this department must follow the conservative approach.

Specific Condition 5.A.4(b): The submission of the manufacturer's chemical resistance recommendations is sufficient to fulfill this condition adequately.

Specific Condition 5.A.4(c): The proposal to install perforated PVC pipe to evaluate amount and type of gas generation has merit. Further details should be submitted so that agreement can be reached as to the effectiveness of this demonstration. Should this system be left in as a permanant vent, this up-front agreement of design and installation plans may eliminate later need for reinstallation of the vent.

Terry

May 15, 1984

TO: Larry Aubuchon, Detroit District, HWD

FROM: Terry McNiel, Services Unit, HWD

SUBJECT: Ford - Allen Park Claymine Landfill

The company's May 1, 1984 submittal of engineering plans for Hazardous Waste Cell I have been reviewed. These plans address the repair of the clay dike along the eastern edge of the cell, relocation of the leachate collection sump and modified leachate collection system design and construction details. The following areas need clarification and/or need to be adequately addressed to meet Act 64 requirements:

1. Requirements of R299.6418(a) and (b):

   a. Type and gradation of collection system sand.
   b. Compatibility of polyethylene pipe with waste leachate.
   c. Compatibility of concrete manhole with waste leachate.
   d. Strength requirements and design specifications for the leachate collection pipe.
   e. Procedures and schedule for leachate removal.
   f. Demonstration that the sump capacity will handle one months leachate but is not less than 4,000 liters.
   e. Collection sand must function without clogging.

2. Operating license requirements:

   a. It must be shown that a maximum of 6 inches of hydraulic head is maintained at all times.
   b. Provision for construction certification must be provided.
   c. Change orders must be approved in writing by the Director prior to the initiation of construction.

3. The sump area sand bedding of 5 feet appears excessive. I have concerns of the sand filling with water and/or leachate providing up to 5 feet of hydraulic head at that point.

4. A grain size distribution for the pea gravel around the leachate collection piping should be provided.

5. It is not clear exactly where the dikes at the edge of the existing fill are being proposed. This, in addition to the exact location of the existing fill should be provided.

6. The permeability of the proposed dike should be a maximum of 1×10^{-7} cm/sec.

7. Procedures and a schedule for repair of the broken leachate piping through the sight berm must be provided.

8. The method of dike (in sight berm) repair, if needed, should be provided. This should include at a minimum: compaction and permeability required, minimum width and height, and quality control procedures.

9. The method and timing for the temporary berm placement and removal should be provided.

10. I would recommend that partial closure of the existing fill area (to include newly placed workbench area) be designed/approved/constructed as part of these construction activities.

Please give me a call if any clarification is needed.

fb

Ford Motor Company

3001 Miller Road
Dearborn, Michigan 48121

May 10, 1984

RECEIVED
MAY 14 1984

Mr. Larry AuBuchon
Hazardous Waste Division
Michigan Department of Natural Resources
Detroit District Office
1120 West State Fair
Detroit, MI 40203

Subject: Ford Allen Park Clay Mine
MID 980568711

Dear Mr. AuBuchon:

Your letter of April 12, 1984, asserts that the subject facility is "not in compliance" with Specific Conditions 5.A.4(a), 5.A.4(b), and 5.A.4(c) of the facility's license. We do not believe that this is the case. As noted below, we believe adequate documentation has been provided to the MDNR with regard to the specified permit conditions, as evidenced by the issuance of the license by MDNR on October 22, 1982.

Specific Condition 5.A.4(a) - The facility provided to the Department a Groundwater Waiver Demonstration in 1982 which provided a comprehensive interpretation of the site's hydrogeologic conditions. The background information provided in this document led to the conclusion that the facility was located in an area with a negative hydraulic gradient (artesian aquifer) which precludes the possibility of leachate migration out of the disposal cell during the active life of the facility. The Department accepted this conclusion as evidenced by the leak detection system waiver granted in the facility license.

Recognition and acceptance of these hydrogeologic conditions is fundamental to the development of appropriate permit conditions and their compliance. The April 3, 1984 memorandum to you from Mr. Terry McNiel indicated that MDNR has elected to ignore this previously stated position by apparently not recognizing these acknowledged and proven site hydrogeologic conditions. No alternative interpretation of the site condition is provided by MDNR staff, however. Such a position is unsubstantiated and should be re-evaluated. We take exception to this superficial evaluation by MDNR staff.

Mr. Larry AuBuchon
May 10, 1984
Page 2

Specific Condition 5.A.4(b) - Provided herewith is the manufacturer's specifications which indicate that the proposed leachate collection pipe is compatible with the constituents in the coal tar decanter tar sludge (naphthalene and phenol). Note that the leachate to be handled will be at ambient temperatures, and the hazardous constituents will be much less concentrated than the reagent grade chemical solutions which are found in the manufacturer's specifications. Note also that the additional component in the collection system is the concrete sump which will be epoxy coated to prevent its exposure to the waste and leachate.

Specific Condition 5.A.4(c) - In order to demonstrate if a gas venting system is required for the disposal cells, we are willing to install a perforated PVC pipe vertically into the fill before applying the final cover. This collection pipe will then be monitored to determine any rate of gas generation. If gas is generated, we would agree to revisit this issue to insure the integrity of the final cover.

If [illegible] be [illegible] should [illegible] plans for [illegible] and construction [illegible] now [illegible] later [illegible] and [illegible] gas generation?

Yours very truly,

Ben C. Trethewey, Manager
Mining Properties Department

Attachment

cc: Prof. D. H. Gray

Extra High Molecular Weight
High Density Polyethylene
PE 3408 Industrial Piping System

PLEXCO

... Amsted INDUSTRIES

APPLICATION NOTE NO. 6

Chemical and Environmental Considerations

Chemical Resistance of PLEXCO Polyethylene

PLEXCO PE 3408 EHMW high density polyethylene pipe has outstanding chemical resistance, making it an ideal piping material for harsh chemical environments and highly corrosive systems. This stability under chemical attack, when coupled with superior abrasion resistance, makes PLEXCO PE 3408 polyethylene an exceptional piping material for many industrial and slurry applications.

Any chemical attack of polyethylene is either a swelling phenomenon causing the plastic to soften, or a direct attack on the polymer structure. If the chemical causing the polyethylene to swell is completely removed, the plastic generally returns to its original condition. A direct chemical attack on the polymer may result in chain scission, cross-linking, oxidation, and substitution reactions. These reactions may cause profound changes in the original properties of the polyethylene which cannot be restored by the removal of the chemical.

Below are chemical resistance data for a wide variety of chemicals. Additional chemical resistance data for polyethylene pipe may be found in the Plastic Pipe Institute's Technical Report PPI-TR-19 "Thermoplastic Piping for the Transport of Chemicals." Because the particular conditions of each application will vary, it is recommended that this information be used only as a preliminary guide to the resistance behavior of polyethylene pipe.

Resistance to Stress Cracking and Corrosion

Because polyethylene is non-conducting, it is immune to galvanic and electrochemical effects. In addition, polyethylene will not corrode in the sense that metals do. Both inside and out, PLEXCO polyethylene pipe resists rust, rot, pitting, and other common causes of failure in metallic piping systems.

Some polyethylenes may fail by environmental stress cracking due to the combined actions of stress and the environment. Stress cracking is the slow growth and propagation of cracks by the action of sensitizing agents on minute surface flaws in a stressed or strained materials.

The polymer structure, molecular weight, and the molecular weight distribution will affect the stress crack resistance of the polyethylene. PLEXCO's EHMW high density polyethylene shows excellent resistance to stress cracking.

Environmental Effects

PLEXCO polyethylene pipe will not degrade due to biological effects. Polyethylene is not digestible and is not generally attacked by burrowing insects or worms. The exceptionally smooth surface of polyethylene pipe disallows growth of algae or other marine life on the pipe walls, especially under conditions of flow. Occasionally polyethylene piping smaller than 4 in. IPS that has been buried in the path of burrowing rodents, will be damaged by them. If this is anticipated, burial more than 3 feet below the surface is recommended. In areas of heavy rodent population, repellents may be necessary.

Sunlight and Thermal Effects

To protect the piping material from ultraviolet radiation, most polyethylene pipe formulations include carbon black or some other ultraviolet screening substance.

PLEXCO PE 3408 pipe can be used over a wide temperature range. With a brittleness temperature (ASTM D-746) of −180°F it performs very well at subambient temperatures. In pressurized systems, it can be used up to 140°F; up to 180°F for non-pressure applications. However, elevated temperatures reduce the effective operating pressure of polyethylene piping systems. To determine the pressure rating for pipe at a temperature above ambient, multiply the 73° rating by the following factor:

FOR PRESSURE RATING AT	MULTIPLY 73° RATING BY
40°F	1.20
60°	1.08
73°	1.00
100°	0.78
120°	0.63
140°	0.50

Temperature fluctuations experienced in surface installations need to be taken into consideration when designing a piping system. Polyethylene's high thermal expansion coefficient of 9×10^{-5} in/in/°F may lead to lateral movement of the pipeline. The results of this movement can be compensated for by snaking the pipe line or installing expansion loops.

Chemical Resistance Key:

x = resistant	swelling < 3% or weight loss < 0.5%, elongation at break not substantially changed	— = not resistant	swelling > 8% or weight loss > 5% and/or elongation at break reduced by > 50%
/ = limited resistance	swelling 3-8% or weight loss 0.5-5% and/or elongation at break reduced by < 50%	D = discoloration	

Medium	73°F	140°F
Acetaldehyde, gaseous	x	/
Acetic acid (10%)	x	x
Acetid acid (100%) (glacial acetic acid)	x	/D
Acetic anhydride	x	/D
Acetone	x	x
Acetylene tetrabromide	**/to—	—
Acids, aromatic	x	x
Acrylonitrile	x	x
Adipic acid	x	x
Allyl alcohol	x	x
Aluminium chloride, anhydrous	x	x
Aluminum sulphate	*x	x
Alums	x	x
Ammonia, gaseous (100%)	x	x
Ammonia, liquid (100%)	x	x
Ammonium chloride	*x	x
Ammonium fluoride, aqueous (up to 20%)	x	x
Ammonium nitrate	*x	x
Ammonium sulphate	*x	x
Ammonium sulphide	*x	x
Amyl acetate	x	x
Aniline, pure	x	x
Anisole	/	—
Antimony trichloride	x	x
Aqua regia	—	—
Barium chloride	*x	x
Barium hydroxide	*x	x
Beer	x	x
Beeswax	x	**/to—
Benzene	/	/
Benzenesulphonic acid	x	x
Benzoic acid	*x	x
Benzyl alcohol	x	xto/
Borax, all concentrations	x	x
Boric acid	*x	x
Brine, saturated	x	x
Bromine	—	—
Bromine vapour	/	
Butanetriol	x	x
Butanol	x	x
*Butoxyl	x	/
Butyl acetate	x	/
Butyl glycol	x	x

*aqueous solutions in all concentrations

Medium	73°F	140°F
Butyric acid	x	/
Calcium chloride	*x	x
Calcium hypochlorite	*x	x
Camphor	x	/
Carbon dioxide	x	x
Carbon disulphide	/	
Carbon tetrachloride	**/to—	—
Caustic potash	x	x
Caustic soda	x	x
Chlorine, liquid	—	—
Chlorine bleaching solution (12% active chlorine)	/	—
Chlorine gas, dry	/	—
Chlorine gas, moist	/	—
Chlorine water (disinfection of mains)	x	
Chloroacetic acid (mono)	x	x
Chlorobenzene	/	—
Chloroethanol	x	xD
Chloroform	**/to—	—
Chlorosulphonic acid	—	—
Chromic acid (80%)	x	—D
Citric acid	x	x
Coconut oil	x	/
Copper salts	*x	x
Corn oil	x	/
Creosote	x	xD
Cresol	x	xD
Cyclohexane	x	x
Cyclohexanol	x	x
Cyclohexanone	x	x
Decahydronaphthalene	x	/
Desiccator grease	x	/
Detergents, synthetic	x	x
Dextrin, aqueous (18% saturated)	x	x
Dibutyl ether	xto/	—
Dibutyl phthalate	x	/
Dichloroacetic acid (100%)	x	/D
Dichloroacetic acid (50%)	x	x
Dichloroacetic acid methyl ester	x	x
Dichlorobenzene	/	—
Dichloroethane	/	/
Dichloroethylene	—	—
Diesel oil	x	/
Diethyl ether	xto/	/
Diisobutyl ketone	x	/to—
Dimethyl formamide (100%)	x	xto/

Medium	73°F	140°F
Emulsifiers	x	x
Esters, aliphatic	x	xto/
Ether	xto/	/
Ethyl acetate	/	—
Ethyl alcohol	x	x
Ethyl glycol	x	x
Ethyl hexanol	x	x
Ethylene chloride (dichloroethane)	/	/
Ethylene diamine	x	x
Fatty acids (>C^6)	x	/
Ferric chloride	*x	x
Fluorine	—	—
Fluorocarbons (e.g. *Frigen)	/	—
Fluosilicic acid, aqueous (up to 32%)	x	x
Formaldehyde (40%)	x	x
Formamide	x	x
Formic acid	x	
Fruit juices	x	x
Fruit pulp	x	x
Furfuryl alcohol	x	xD
Gelatine	x	x
Glucose	*x	x
Gycerol	x	x
Gylcerol chlorohydrin	x	x
Glycol (conc.)	x	x
Glycolic acid (50%)	x	x
Glycolic acid (70%)	x	x
Halothane	/	/
Hydrazine hydrate	x	x
Hydrobromic acid (50%)	x	x
Hydrochloric acid (all concentrations)	x	x
Hydrocyanic acid	x	x
Hydrofluoric acid (40%)	x	/
Hydrofluoric acid (70%)	x	/
Hydrogen	x	x
Hydrogen chloride gas, moist and dry	x	x
Hydrogen peroxide (30%)	x	x
Hydrogen peroxide (100%)	x	
Hydrogen sulphide	x	x
Iodine, tincture of, DAB 7 (German Pharmacopoeia)	x	/D
Isooctane	x	/
Isopropanol	x	x
Isopropyl ether	xto/	—
Jam	x	x

Medium	73°F	140°F
Keotones	x	xto/
Lactic acid	x	x
Lead acetate	*x	x
Linseed oil	x	x
Magnesium chloride	*x	x
Magnesium sulphate	*x	x
Maleic acid	x	x
Malic acid	x	x
Menthol	x	/
Mercuric chloride (sublimate)	x	x
Mercury	x	x
Methanol	x	x
Methyl butanol	x	/
Methyl ethyl ketone	x	/to—
Methyl glycol	x	x
Methylene chloride	/	/
Mineral oils	x	xto/
Molasses	x	x
Monochloroacetic acid	x	x
Monochloroacetic ethyl ester	x	x
Monochloroacetic methyl ester	x	x
Morpholine	x	x
Naptha	x	/
Naphthalene	x	/
Nickel salts	*x	x
Nitric acid (25%)	x	x
Nitric acid (50%)	/	—
Nitrobenzene	x	/
o-Nitrotoluene	x	/
Octyl cresol	/	—
Oils, ethereal	/	/
Oils, vegetable and animal	x	xto/
Oleic acid (conc.)	x	/
Oxalic acid (50%)	x	x
Ozone	/	—
Ozone, aqueous solution (drinking water purification)	x	
Paraffin oil	x	x
Perchloric acid (20%)	x	x
Perchloric acid (50%)	x	/
Perchloric acid (70%)	x	—D
Petrol	x	xto/
Petroleum	x	/
Petroleum ether	x	/
Phenol	x	xD
Phosphates	*x	x
Phosphoric acid (25%)	x	x
Phosphoric acid (50%)	x	x

The technical data contained herein are guides to the use of PLEXCO polyethylene pipe and fittings. Due to workmanship and other factors over which PLEXCO has no control, PLEXCO makes no guarantee of results and assumes no obligation or liability in conjunction with the use of the herein technical data.

GENERAL OFFICE
Franklin Park, Illinois 60131
3240 North Mannheim Road
(312) 455-0600

Medium	73°F	140°F
Phosphoric acid (95%)	x	/D
Phosphorus oxychloride	x	/D
Phosphorus pentoxide	x	x
Phosphorus trichloride	x	/
Photographic developers, commercial	x	x
Phthalic acid (50%)	x	x
Polyglycols	x	x
Potassium bichromate (40%)	x	x
Potassium borate, aqueous (1%)	x	x
Potassium bromate, aqueous (up to 10%)	x	x
Potassium bromide	*x	x
Potassium chloride	*x	x
Potassium chromate, aqueous (40%)	x	
Potassium cyanide	*x	x
Potassium hydroxide (30% solution)	x	x
Potassium nitrate	*x	x
Potassium permanganate	x	xD
Propanol	x	x
Propionic acid (50%)	x	x
Propionic acid (100%)	x	/
Propylene glycol	x	x
Pseudocumene	/	/
Pyridine	x	/
Seawater	x	x
Silicic acid	x	x
Silicone oil	x	x
Silver nitrate	x	x
Sodium benzoate	x	x
Sodium bisulphite, weak aqueous solutions	x	x
Sodium carbonate	*x	x
Sodium chloride	*x	x
Sodium chlorite (50%)	x	/
Sodium hydroxide (30% solution)	x	x
Sodium hypochlorite (12% active chlorine)	/	—
Sodium nitrate	*x	x
Sodium silicate	*x	x
Sodium sulphide	*x	x
Sodium thiosulphate	x	x
Spermaceti	x	/
Spindle oil	xto/	/
Starch	x	x
Steric acid	x	/
Succinic acid (50%)	x	x

Medium	73°F	140°F
Sugar syrup	x	x
Sulphates	*x	x
Sulphur	x	x
Sulphur dioxide, dry	x	x
Sulphur dioxide, moist	x	x
Sulphur trioxide	—	—
Sulphuric acid (10%)	x	x
Sulphuric acid (50%)	x	x
Sulphuric acid (98%)	/	—
Sulphuric acid, fuming	—	—
Sulphurous acid	x	x
Sulphuryl chloride	—	
Tallow	x	x
Tannic acid (10%)	x	x
Tartaric acid	x	x
Tetrachloroethane	**xto/	—
Tetrahydrofurane	**xto/	—
Tetrahydronaphthalene	x	/
Thionyl chloride	—	—
Thiophene	/	/
Toluene	/	—
Transformer oil	x	/
Tributyl phosphate	x	x
Trichloroacetic acid (50%)	x	x
Trichloroacetic acid (100%)	x	/to—
Trichloroethylene	**/to—	—
Triethanolamine	x	x
Turpentine, oil of	xto/	/
Tween 20 and 80 (Atlas Chemicals)	x	x
Urea	*x	x
Vaseline	**xto/	/
Vinegar (commercial conc.)	x	x
Viscose spinning solutions	x	x
Waste gases containing		
—carbon dioxide	x	x
—carbon monoxide	x	x
—hydrochlorid acid (all concentrations)	x	x
—hydrogen fluoride (traces)	x	x
—nitrous vitriol (traces)	x	x
—sulphur dioxide (low concentration)	x	x
—sulphuric acid, moist (all concentrations)	x	x
Water glass	x	x
p-Xylene	/	—
Yeast, aqueous preparations	x	x
Zinc chloride	*x	x

STATE OF MICHIGAN

JAMES J. BLANCHARD, Governor

DEPARTMENT OF NATURAL RESOURCES

STEVENS T. MASON BUILDING
BOX 30028
LANSING, MI 48909

RONALD O. SKOOG, Director

Hazardous Waste Div.
1120 W. State Fair Ave
Detroit, MI 48203

April 12, 1984

RECEIVED
APR 16 1984
HAZARDOUS WASTE DIVISION

Mr. Ben C. Trethewey, Manager
Mining Properties Department
Ford Motor Company
3001 Miller Road
Dearborn, MI 48121

SUBJECT: Ford Allen Park Clay Mine Landfill MID 980568711

Dear Mr. Trethewey:

A review of your February 24, 1984, submittal has been performed by Terry McNiel, Technical Services Section, Hazardous Waste Division. His comments are relating to Specific Conditions 5.A.4(a), 5.A.4(b) and 5.A.4(c) of your license. Based on Mr. McNiel's comments (enclosure) it was determined that you are still not in conformance with the requirements of your license.

You are requested to provide the necessary documentation to address these shortcomings no later than May 12, 1984. If you have any questions, please contact me or Terry McNiel.

Sincerely,
HAZARDOUS WASTE DIVISION

Larry AuBuchon

Larry AuBuchon
DETROIT DISTRICT OFFICE

LA:pf
Enclosure

cc K. Burda
J. Bohunsky
T. McNiel

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

INTEROFFICE COMMUNICATION

April 3, 1984

TO: Larry Aubuchon
Compliance Section, Detroit District
Hazardous Waste Division

FROM: Terry McNiel
Technical Services Section
Hazardous Waste Division

SUBJECT: Ford-Allen Park Landfill

I have reviewed the February 16, 1984, letter from Dr. Donald H. Gray to Mr. David Miller to determine whether Specific Condition 5.A.4(a) has been satisfied. There are, again, assumptions made by Ford's consultant regarding the leachate chemical makeup and the clay mineralogy with no documentation of saturated conditions in the silty clay at or near trench bottom to substantiate upward flow. If saturation exists, the leachate collection system must be designed to handle this inflow.

The facility has had the requirement of a leak detection system waived based on the site's clay characteristics. Assurance that the containment system will function in a manner such that this backup system is not needed must be provided. The company has asked for and received variances and waivers and is now asking to waive the requirement that the original waiver was based on!

It is agreed that a triaxial-type, flexible, pressurized jacket permeameter should be used. A positive gradient of 1.0 (assuming non-saturation) on an undisturbed sample should simulate worst case conditions.

In regards to Specific Condition 5.A.4(b), the chemical make up of the leachate needs to be compared to the manufacturer's chemical resistance recommendations for the PVC piping.

For the requirement of gas venting in Specific Condition 5.A.4(c) to be waived, it must be shown that no gases will be generated. A procedure to demonstrate this should be submitted for review. The integrity of the final cap must be assured.

If there are any questions, please give me a call.

April 3, 1984

TO: Larry Aubuchon
Compliance Section, Detroit District
Hazardous Waste Division

FROM: Terry McNiel
Technical Services Section
Hazardous Waste Division

SUBJECT: Ford-Allen Park Landfill

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If there are any questions, please give me a call.

amk

January 23, 1984

TO: Larry Aubuchon, Compliance Section, Detroit District

FROM: Terry McNiel, Technical Services Section

SUBJECT: Ford-Allen Park Landfill

I have reviewed the report "Containment Integrity of Allen Park Clay Mine/Landfill" by Professor Gray. Specifically, my review was aimed at determining whether it satisfies Specific Condition 5.A.4(a),(b),(c) of the landfill's Act 64 license. I have the following comments:

1) Dr. Gray concludes that it is unlikely that organics present in the waste will cause a permeability increase. He reasons that there is an absence of any substantiation in the published technical literature for such an increase. However, he provides no cite of any literature which shows no increase in permeability.

   He also assumes that the leachate will contain approximately 500 ppm of phenols due to the decanter tar sludge. He disregards taking any affects of the napthaline into account.

   Because of the uncertain nature of the leachate generated at the site, these assumptions may or may not be valid.

   We therefore do not consider Specific Condition 5.A.4(a) to be satisfied. We would accept, however, compatability testing between the <u>actual</u> leachate being generated and the on-site clay being used for containment.

2) Specific Condition 5.A.4(b) requires that the leachate collection system components be compatible with the leachate. Once the system is designed, the manufacturer's compatibility recommendations for any piping should be evaluated. This submittal doesn't address this subject.

3) Specific Condition 5.A.4.(c) requires compatibility between any generated gases and the clay cap. This submittal does not address this subject.

kjh

ROUGE STEEL COMPANY

3001 Miller Road
P. O. Box 1699
Dearborn, Michigan 48121-1699

February 15, 1984

Mr. Larry Aubuchon
Detroit District Office
Michigan Department of Natural Resources
Box 30028
Lansing, Michigan 48909

RECEIVED
FEB 16 1984
GQD DETROIT DIST

Subject: Ford Motor Company Allen Park Clay Mine
EPA I.D. #MID 908568711

Dear Mr. Aubuchon:

This is in reply to your letter dated January 31, 1984, which requested additional response to your concerns regarding Specific Condition Section items 4(a), (b), and (c) of 5.A. in the subject facility's Act 64 Hazardous Waste Operating License.

1. With respect to Specific Condition item 5.A. 4(a), we have requested our hydrogeologic consultant, Prof. Donald Gray of the University of Michigan College of Engineering, to provide his views relevant to your need for the suggested compatibility testing. Our response to this item is therefore in preparation and will be submitted on or about March 1, 1984.

2. Concerning Specific Condition item 5.A. 4(b), please note that the materials utilized in our leachate collection system are epoxy coated concrete and PVC collection pipe. The PVC piping has been installed in the coke tar decanter sludge collection system at the point of generation for more than twenty years and is the recommended material for the job. Coating of the concrete sump with epoxy will prolong the life of the concrete in the unlikely event of its exposure to any highly acidic leachate.

3. Specific Condition 5.A. 4(c) requires compatibility between any generated gases and the clay cap. According to the EPA development document for coke tar decanter sludge (K087), the composition consits of approximately 97% elemental carbon and 3% condensed tar materials. As there are no decomposition products generated from elemental carbon and condensed tar materials, there will be no gases. Accordingly, there should be no concern relative to the integrity of the cap resulting from gas generation.

Yours very truly,

Ben C. Trethewey

Ben C. Trethewey, Manager
Mining Properties Department

RECEIVED
FEB 24 1984
HAZARDOUS WASTE DIVISION

DSM:dp

cc: Mr. Terry McNiel

Ford Motor Company

3001 Miller Road
Dearborn, Michigan 48121

February 24, 1984

Mr. Larry Aubuchon
Detroit District Office
Michigan Department of Natural Resources
1120 West State Fair
Detroit, MI 48203

RECEIVED
FEB 27 1984
HAZARDOUS WASTE DIVISION

Subject: Ford Allen Park Clay Mine
EPA I.D. #MID 908568711

Dear Mr. Aubuchon:

This is in reply to your letter dated January 31, 1984 which requested additional response to your concerns regarding Specific Condition Section item 5.A.4(a) in the subject facility's Act 64 Hazardous Waste Operating License.

As indicated in our letter to you dated February 15, 1984, we have requested our hydrogeologic consultant, Prof. Donald Gray of the University of Michigan College of Engineering, to provide a response relevant to your request for the suggested compatibility testing. Accordingly, please find Prof. Gray's reply enclosed herewith.

In view of the hydrogeological documentation provided by this report, in addition to prior submittals, we concur with our consultant that further compatibility testing is unwarranted.

If further discussion is necessary, please contact Mr. David Miller at (313) 322-0700.

Yours very truly,

Ben C. Trethewey, Manager
Mining Properties Department

DSM:dp
Enclosure
cc: Mr. T. McNiel

bcc: Messrs. J. A. Esper
C. Kircos
V. H. Sussman
S. H. Vaughn

1704 Morton Street
Ann Arbor, MI 48104

16 February 1984

Mr. David S. Miller
Mining Properties Department
Rouge Steel Company
3001 Miller Road
Dearborn, MI 48121

RE: Allen Park Clay Mine/Landfill

Dear Dave:

I have reviewed the memorandum dated January 23, 1984, from Terry McNiel, Technical Services Section, to Larry Aubuchon, Compliance Section, Detroit District, MDNR. The memorandum essentially raises the following objections to the findings and conclusions in my report, viz.,

Objection 1. There is no substantiation nor literature citations to show that organics present in the waste will not increase permeability.

Objection 2. The presence and possible effects of napthalene in the waste are disregarded.

Objection 3. Uncertainties remain about the actual composition and likely nature of the leachate.

Objection 4. The report does not address the question of compatibility between the following:
a) Leachate and leachate collection system components
b) Generated gases and clay cap.

In the opinion of the MDNR reviewer Objections 1,2,and 3 taken together mean that Specific Condition 5.A.4 (a) of Act 64 license is not satisfied. The reviewer goes on to say, however, that they (MDNR) would accept compatibility testing between actual leachate being generated and the on-site clay being used for containment. I will respond herein to these stated objections and opinion. Objection 4 which pertains to Specific Condition 5.A.4 (b) and (c) is outside the scope and original charge of my investigation.

Objection 1 is a version of the "guilty until proved innocent" syndrome. I understand and even sympathize with this approach in matters which deal with the release of potentially hazardous substances into the environment. There is, however, considerable substantiation in the published technical literature for the contention that organics present in low concentrations in aequous leachate will not increase the permeability of dense clays.

Leachate permeability tests on sand-clay columns packed to bulk densities within the range of densities of natural clays (Cartwright et al., 1977) have shown that permeability actually decreased with passage of leachate (containing organics). These tests were continued for periods up to nine months. Decreases were even more pronounced for raw, unsterilized leachate. In addition to permeability reduction from the passage of leachate, Griffin and Shimp (1976) have shown that heavy metal ions (Pb, Zn, Cd, Hg) are strongly attenuated by clay. Organics that were present in the leachate were only moderately attenuated by the clay; they did not increase hydraulic conductivity. We have also conducted long term leachate permeability tests ourselves on a silty clay almost identical in composition to the clay underlying the Allen Park Clay Mine/Landfill site (Gray, 1982) and found the same results, i.e., no increase in permeability was observed. A chemical analysis of the leachates used in all these permeability tests is attached. Note the presence of napthalene in one of the leachates--a constituent whose presence and influence the MDNR reviewer claimed we had not considered. /Note: Cited references are listed in an attachment to this letter report./

It is important to emphasize again the fact that leachate permeability tests conducted by Anderson (1982) are totaly unrepresentative of conditions at the Allen Park site. These tests are often cited as an example of the deleterious influence of organic solvents on clay liner permeability. Anderson's tests are unrepresentative and irrelevant for the following reasons:

1. He used pure organic solvents. The leachate at the Allen Park Clay Mine/Landfill will be an aequous extract containing very low concentrations of organics.

2. He forced the solvents through clays at extremely high, positive gradients. Anderson used positive gradients ranging from 60 to 300. At the Allen Park site there will be negative (reverse) gradients ranging on the order of -0.3 (worst case) to -2.7.

Other objections can also be cited in regard to Anderson's test procedures and results. He used a rigid wall permeameter which permits channeling between sample and container. The recommended procedure to avoid this potential problem is to use a flexible, pressurized jacket. Large reported increases in permeability should be viewed with some skepticism when rigid wall permeameters have been employed.

Green et al. (1981) have investigated in great detail the characteristics of organic solvents that affect their rate of movement (permeability) in compacted clay. They measured the equilibrium permeability of three clays (a clay shale, a fire clay, and kaolinite) to the following solvents: benzene, xylene, carbon tetrachloride, trichloroethylene, acetone, methanol, glycerol, and water. Their study showed that it is the hydrophilic or hydrophobic nature of the solvent (as measured by the octanol/water partitioning coefficient or roughly by the dielectric constant) and not the viscosity/density ratio that is important in predicting a solvents rate of flow through clays. According to their findings water, which has a high dielectric constant, always exhibited the highest permeability. In addition, they found that the packed clay density is crucial in determining how permeable a clay will be to a given solvent. At high bulk densities (on the order of 115 pcf or 1.85 g/cc) the solvent characteristics became less important in differentiating permeability response.

Green et al. (1981) also observed that solvents of low dielectric constant (e.g. xylene and carbon tetrachloride) tended to cause shrinkage and cracking of some of the clays. This phenomenon, known as syneresis, can and eventually did cause an apparent permeability increase in some of the clays that were tested. The same phenomenon was reported by Anderson(1982) in some of his experiments. It must be emphasized again, however, that the effect has only been observed and reported when several pore volumes of pure, low-dielectric organic solvents are forced at very high gradients through clay columns. These conditions simply do not occur at the Allen Park Clay Mine/Landfill site.

On the contrary, the conditions at the Allen Park site are ideal for effective containment, viz.,

1. The site is underlain by a thick ($X \geq 25$ ft) section of dense, competent silty clay ($\gamma_D = 115$ pcf) with a very low hydraulic conductivity ($k = 2 \times 10^{-8}$ cm/sec)

2. A negative hydraulic gradient exists at the site as result of artesian conditions in the underlying aquifer. Even under worst case assumptions (viz., leachate levels rising to the top of the landfill) a negative gradient of -0.3 will still be present.

3. The leachate consists of very low concentrations of organic and inorganic solutes in an aqueous solution as opposed to a pure solvent.

Under these conditions advective transport or hydraulic seepage ceases to dominate pollutant movement across a clay barrier (see Gilbert and Cherry, 1983; Tallard, 1984). Instead, diffusion under chemical concentration gradients becomes more important, and it is this transport mechanism that must be evaluated carefully. I have dealt with this problem both in my original report and in my subsequent letter report to Mr. Mark Young, Wayne Disposal, Inc., dated 25 September 1983. I showed that even under worst case assumptions of no partitioning or attenuation of pollutants and minimum, negative hydraulic gradients breakthrought times would be on the order of thousands of years. Interestingly, if the calculations are repeated allowing the hydraulic conductivity or permeability to double or even triple, the breakthrough time increase even more because now the counter advective flow is more effective in opposing the downward diffusion of solutes along their concentration gradient.

I come now to the MDNR comments about requiring compatibility testing (whatever that means) between actual leachate and the clay liner material. Unfortunately, the procedure, rationale, etc. for such tests are not specified. What is being required ...that the leachate be forced under high hydraulic gradients through a thin sample of the silty clay? The results or significance of such a test would be ambiguous at best and meaningless at worst in this case. In my opinion, such tests would be an exercise in futility and irrelevance given the condition and circumstances at the Allen Park Clay Mine/Landfill site.

Breakthrough times in diffusion controlled transport are extremely sensitive to thickness of the barrier. In order to replicate conditions in the field at Allen Park, compatibility or flow tests should be run on a sample column 25 feet high under a negative gradient no less than -0.3. After a wait time of thousands of years such a test would merely confirm what is already demonstrable.

It is my professional opinion that in this instance the requirement for compatibility testing and concern over permeability is a diversion from the real issue which is the likelihood of diffusion transport of solute across the clay. I have shown that this will not be a problem at the Allen Park Clay Mine/Landfill site because of the thickness, competency, and density of the underlying clay together with the existence of a negative gradient.

I find it baffling that MDNR can approve a thin, clay slurry wall for a toxic waste site (see Consent Judgment, U.S. District Court, U.S. Envl. Protection Agency and The State of Michigan, Plaintiffs, vs. Velsicol Chemical Corp., Defendant) based on meagre and inadequate evaluation whilst insisting on irrelevant tests for a thick, natural clay containment system at Allen Park that is ideal in nearly every respect.

Sincerely,

Donald H. Gray

Donald H. Gray
Professor of Civil Engineering

Attachments

ATTACHMENT NO. 1 - CITED REFERENCES

Anderson, D. (1982). Does landfill leachate make clay liners more permeable? Civil Engineering, ASCE, Vol. 52, pp. 66-69

Cartwright, K., Griffin, R.A., and Gilkeson, R.H. Migration of landfill leachate through glacial tills, Groundwater, Vol. 15, No. 4, pp. 294-305

Gilham, R.W. and Cherry, J.A. (1983). Predictability of solute transport in diffusion-controlled hydrogeologic regimes, Proceedings, Symposium on Low-Level Waste Disposal, U.S. NRC, NUREG/CP-0028, Conf-820911, Vol. 3, pp. 379-410

Gray, D.H. (1982). Influence of leachate on clay liner permeability, Wayne Disposal landfill site, Report prepared for Wayne Disposal, Inc., September 1982

Green, W.J., Lee, F.G., and Jones, R.A. (1981). Clay-soils permeability and hazardous waste storage, Journal of WPCF, Vol. 53, No. 8, pp. 1347-1354

Griffin, R.A. and Shimp, N.F. (1976). Attenuation of pollutants in municipal landfill leachate by clay minerals, Cincinnati Ohio: Final Report for U.S. Envl Protection Agency, Contract 68-03-0211

Tallard, G. (1984). Slurry trenches for containing hazardous wastes, Civil Engineering, ASCE, Vol. 54, No. 2, pp. 41-45

ATTACHMENT NO 2

Table 2. Chemical Analysis of Landfill Leachates

Analysis	DuPage County Landfill-mg/l	Wayne Disposal Landfill-mg/l
Na	748	3400
K	501	–
Ca	47	46
Mg	233	370
Cu	<0.1	0.55
Zn	18.8	5.0
Pb	4.46	0.91
Cd	1.95	0.10
Ni	0.3	0.40
Hg	0.0008	0.010
Cr	<0.1	0.31
Fe	4.2	7.77
Mn	<0.1	–
Al	<0.1	–
NH_4	862	1540
As	0.11	0.0044
B	29.9	<0.005
Si	14.9	–
Cl	3484	5800
SO_4	<0.1	200
NO_3	–	<0.1
HCO_3	–	6920
COD	1340	2160
TOC	–	2500
TSS	–	512
pH	6.9	7.6
Spec. Cond. (mmhos/cm)	10.2	28.0
Equiv. TDS	6528	17,920
Organics:		
organic acids (phenol)	0.3	3.6
toluene	–	0.45
napthalene	–	0.44
chlorobenzene	–	0.008

STATE OF MICHIGAN

JAMES J. BLANCHARD, Governor

DEPARTMENT OF NATURAL RESOURCES

STEVENS T. MASON BUILDING
BOX 30028
LANSING, MI 48909

RONALD O. SKOOG, Director

January 31, 1984

Mr. Ben C. Trethewey, Manager
Ford Motor Company
Mining Properties Department
3001 Miller Road
Room 2042 ROB
Dearborn, Michigan 48121

Subject: Allen Park Clay Mine, Wayne County (MID 908568711)

Dear Mr. Trethewey:

Thank you for your letter dated December 6, 1983 responding to the concerns raised in my November 23, 1983 letter. I consider your response to items 1, 2, 3 and 8 acceptable at this time and will evaluate the adequacy of your program during future inspections.

This Division has acknowledged your compliance with Specific Condition 18D2 which was necessary to address item 7 in my letter. I have requested additional information from the City of Allen Park and the City of Detroit which will aid in determining your compliance with Specific Condition 18D1 (item 6).

The construction notification given to this Department 3 or 4 months prior to actual construction is not acceptable. The condition in the permit states, "shall notify the Director of construction progress". I request that in the future a schedule of construction activities be provided to enable us to have a better working relationship and allow this office to monitor the construction while in progress.

The rationale and documentation as to complying with items 4a, b, c and 5a of the Specific Condition Section has been reviewed by Terry McNeal, Technical Services Section, HWD and found deficient. Mr. McNeal's memo discussing the deficiencies has been enclosed. You are requested to submit a time schedule by February 15, 1984 which would provide a time frame for addressing the deficiencies for eventual compliance with this condition of your license.

If you have any questions, please contact me.

Sincerely,
HAZARDOUS WASTE DIVISION

Larry AuBuchon

Larry AuBuchon
DETROIT DISTRICT OFFICE

Enclosure

R1026

cc: J. Bohunsky
K. Burda

January 10, 1984

Mr. Ben C. Trethewey, Manager
Mining Properties Department
Ford Motor Company
3001 Miller Road
Dearborn, Michigan 48121

Dear Mr. Trethewey:

Your December 9, 1983 letter requesting modifications to your artesian monitoring wells at the Allen Park Clay Mine has been received by this office. The modifications, to include a stainless steel and silicone rubber plug 2 1/2 feet below grade, tygon tubing and a pressure gage accurate to 0.2 inch are hereby approved by the Hazardous Waste Division.

Please note that you should also submit this request to the appropriate Act 641 office for their approval prior to implementing this system.

Sincerely,

Terrence J. McNiel, Geologist
Technical Services Section
Hazardous Waste Division
517-373-2730

cc: L. Aubuchon
D. Booth
F. Belobraidich
File

A

ORIGINAL to EACH FACILITY FILE

Ford - Allen Park file

October ~~19~~ 26, 1983

TO: Stewart Freeman, Assistant Attorney General
Environmental Protection Division

FROM: Jack D. Bails, Chief
Environmental Enforcement Division

SUBJECT: Contested Case Hearings - 1979 PA 64
Hazardous Waste Disposal Facility Licenses

As we discussed, I am hereby referring five (5) requests for contested case hearings to you. They are:

1. Wayne Disposal
2. Ford - Allen Park Clay Mine
3. Ford - Saline
4. Environmental Waste Control Inc.
5. Edward C. Levy Company

A file copy, a short summary of the issues, and the Department position on each issue are attached.

We believe that some of these cases can be resolved through negotiation with the companies, and would like to meet with the companies as soon as possible to begin discussions. Gary Marx will be contacting you shortly to discuss the next steps to be taken to move these matters ahead.

JDB:GM:jp
Attachment

CC: Howard ✓

RECEIVED
OCT 27 1983
HAZARDOUS WASTE DIVISION

FORD MOTOR COMPANY
ALLEN PARK CLAY MINE
Summary of Issues

The duration of license, condition 28 of part I, conditions 2, 4.A., 9.B.1., 10.A, 10.C., 12.C, 16, 15.B., 18, 17 and 19, Tables 1, 2A, 2B, 4 and 5, and numerous general conditions of Ford Allen Park Clay Mine's Disposal Facility Operating License are being contested by the company. The license was issued on October 22, 1982.

1. Ford objects to the four-year license period and claims license should be valid for ten years. The four-year period is consistent with other licenses which include schedules of compliance. The shortened license allows Department review of company compliance with upgrade requirements before a long-term license is issued.

2. Part I, Section 28. The Department agrees that this section should be deleted.

3. Part II, Sections 2 and 4.A. - Ford objects to being restricted to the types and quantities of waste listed in the license. The Department cannot compromise on this issue and is willing to contest it in a hearing. Staff feels it is unlikely this issue will be resolved short of a hearing.

4. Part II, Section 9.B.1. Ford claims compaction standards in this section are contrary to the rules. The Department agrees and will adjust the license condition to coincide with the rules.

5. Part II, Section 10.A. Ford claims the leachate collection system specified in the license is unnecessarily elaborate to meet the rules. The Department is willing to review any alternate proposal from the company and will approve if such proposal meets the standards of the rules.

6. Part II, Section 10.C. Ford contests the requirement for Class II sand in the leachate collection system. The Department may allow some variation from this standard but must have material which is consistent and can assure the necessary performance.

7. Part II, Section 12.C. Ford contests the requirement for a wheelwash station. The Department will review for approval any proposal which assures that no waste materials are tracked out of the site, or allowed to wash into surface drains.

8. Part II, Section 16, and Tables 2A and B. Ford claims that the artesian condition of the groundwater at the site precludes the possibility of off-site migration of contaminants so no groundwater monitoring should be required. The Department agrees that this feature of the groundwater is a favorable condition and is likely to preclude off-site migration, but monitoring must be undertaken to assure that none occurs.

Ford further contends that if monitoring is to be required, the program in the license is inconsistent with the requirements of RCRA and ignores previous monitroing results. The Department is willing to discuss specific changes Ford may request.

9. Part II, Section 15.B. Ford contests the license prohibition against reintroduction of leachate into the fill area. This item is non-negotiable as there is no sound engineering reason for this practice in such a facility.

10. Part II, Section 18, and Tables 4 and 5. Ford contests leachate monitoring requirements with the following claims:

    a. Monitoring should be consistent with Detroit sewer ordinances. The Department feels that because of the type of waste (coke tar) at this facility, a much broader range of compounds must be monitored than required in the relatively unsophisticated Detroit ordinance.

    b. GC-MS technology is not necessary to accomplish proper monitoring. The Department will entertain other proposals but is not aware of any others which would be acceptable. The response/noise ratio requirements may be somewhat flexible.

    c. Act 64 does not regulate discharge to sewers. Amendments to Act 64 adopted April 1, 1983 have eliminated the previous exemption.

11. Part II, Section 17. Ford contests some of the parameters for surface water monitoring. The Department will entertain proposals for specific changes.

12. Part II, Section 19. Ford contests the requirement for an air monitoring program. The only possible point of negotiation is the duration of the program should the first year of data shows no problems.

13. Ford objects to the inclusion of numerous general provisions in the license, but does not state any specific problems. Staff contacts with Ford have indicated that this may not be a problem, but any specific problems Ford may have must be identified for the Department to respond.

GM:jp

WAYNE DISPOSAL, INC.
POST OFFICE BOX 5187, DEARBORN, MICHIGAN 48128 • (313) 326-0200

October 20, 1983

Ms. De Montgomery
Michigan Department of
Natural Resources
Hazardous Waste Division
P.O. Box 30038
Lansing, MI 48909

Re: Allen Park Clay Mine, Allen Park, Michigan

Dear Ms. Montgomery:

I received a call from Professor Donald Gray today and learned that you have had a discussion with him recently concerning his report on solute transport through clay liner soils at Allen Park Clay Mine.

As he indicated to you, he has completed additional work on the problem through the use of a computer program he has written. Enclosed is a copy of his letter and the results of this work which were recently submitted to us. The results support the work previously reported by Dr. Gray.

Please let me know if additional information is required concerning the groundwater monitoring variance request for Allen Park Clay Mine.

Sincerely,

WAYNE DISPOSAL, INC.

Mark A. Young

Mark A. Young, P.E.

MAY/ap

Encl.

cc: Mr. David Miller, Rouge Steel Company
Mr. Jerry Amber, Ford Motor Company, SSECO
Professor Donald Gray

1704 Morton Street
Ann Arbor, Michigan
48104

25 September 1983

Mr. Mark Young
Wayne Disposal Company
P.O. Box 5187
Dearborn, MI 48128

RE: Allen Park Clay Mine/Landfill

Dear Mark:

I recently wrote a computer program (*CLAYWALL*) that can be used to calculate solute transport across a clay barrier under combined diffusion and advection (hydraulic flow). The program computes the exit/source concentration ratio (C/Co) as a function of elapsed time (t) on the downstream side of a clay wall or barrier of thickness (X).

The program was written with a clay slurry cut-off wall in mind, but is general enough that it can be used with any clay layer or barrier. The input parameters to the program are:

D_e = efffective diffusion coefficient, ft^2/yr
K = hydraulic permeability, ft/yr
X = thickness of wall or barrier, ft
P = porosity
I = hydraulic gradient...(+) if same direction, (-) if opposite direction to solute concentration gradient
t = elapsed time, yrs

The program is based on the solution to the equation that describes one-dimensional solute transport in a saturated porous medium under both hydraulic and solute concentration gradients. This equation has the following form:

$$C/Co = 0.5[\mathrm{erfc}((X-vt)/\mathrm{sqr}(4D_eK)) + \exp(vX/D)\ \mathrm{erfc}((X+vt)/\mathrm{sqr}(4D_eK))]$$

where: v = ave seepage velocity = (KI/P)

The solution assumes the following conditions:

1. Saturated, one-dimensional flow.

2. No reaction between solutes and porous medium. Chloride typically behaves this way.

3. Diffusion controlled, i.e., the pore water velocity is so low that mechanical mixing is negligible and the dispersion is equal to the effective diffusion coeffficient. (this condition is satisfied when K < 1.0E-07.

I ran the program using data for the silty clay layer underlying the Allen Park ClayMine/Landfill. The following values for the input data were used:

D = 0.102 ft^2/yr (6.3E-06 cm^2/sec)
(published value for clay tills)
K = 0.025 ft/yr (2.5E-08 cm/sec)
X = 30 ft
P = 30 %
I = -0.1,-0.3, and -1.0

The results of the analysis are shown in the attached graph. At a counter hydraulic gradient of -0.3 the exit/source solute concentration ratio does not exceed 0.0001 until 700 years have elapsed. You may recall that a counter hydraulic gradient of -0.3 occurs when the leachate is allowed to rise in the landfill to the ground surface...a worst case scenario. For larger (negative) counter hydraulic gradients the ratios become even smaller. In fact for I < -0.5 (i.e., counter hydraulic gradients larger than 0.5) the ratio C/Co is less than 1.0E-05 at all elapsed times.

These results confirm the findings of my earlier report which were based largely on analogy to solute transport studies in clay aquitards. The present findings are based on analysis of actual soil and site parameters. Keep in mind, also, that the analysis is still quite conservative because it neglects possible adsorption (reaction) of solutes with the clay.

A copy of the computer program and typical output are enclosed. It is written in BASIC and is designed to be run on a personal computer. If you have any questions about the analysis, please feel free to contact me.

Sincerely,

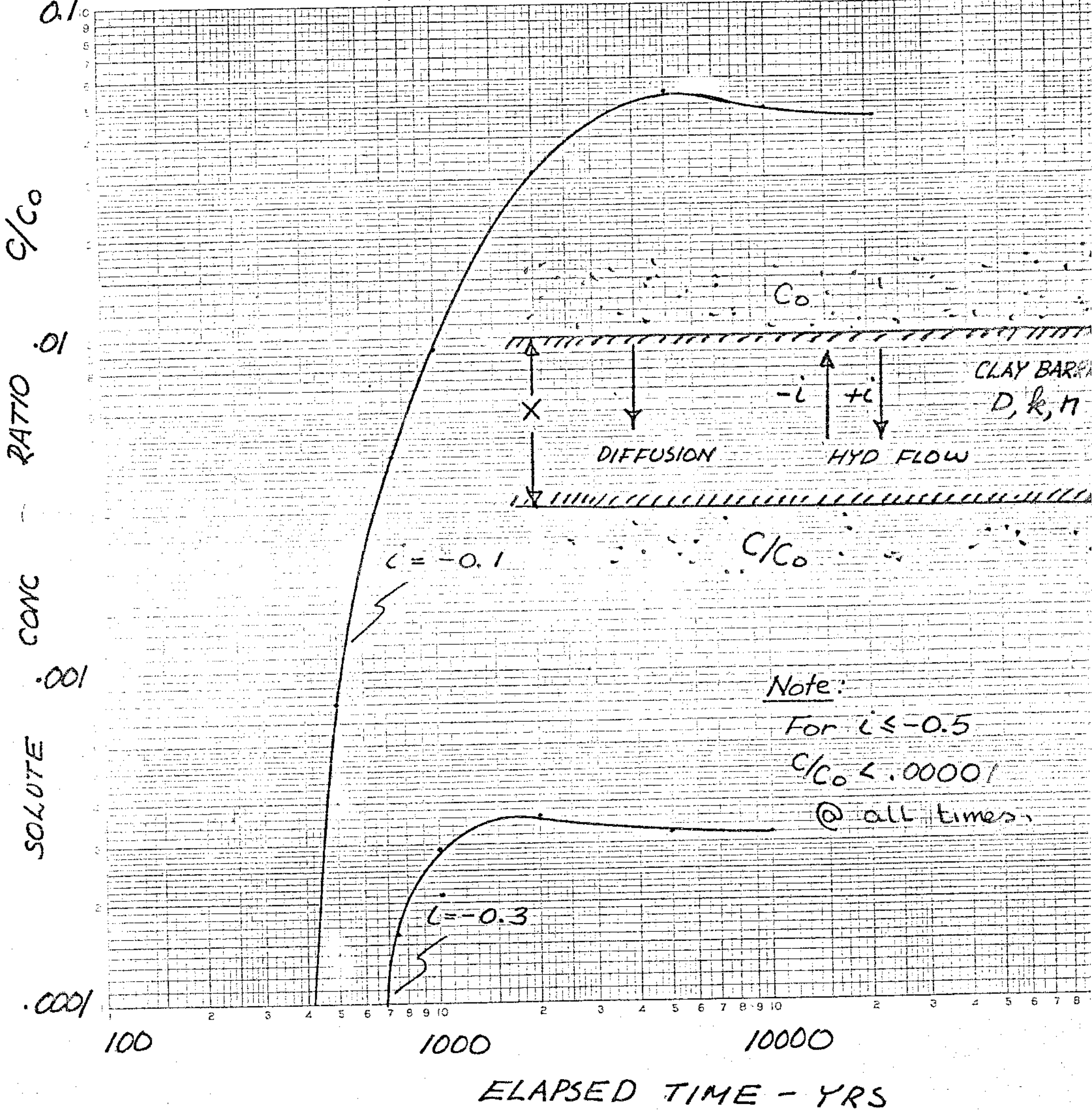
Donald H. Gray

Donald H. Gray
Professor of Civil Engineering

Encl

```
run
Porosity: 0.3
Permeability(ft/yr): .025
Diffusion Coef(ft /yr): 0.102
Wall Thickness: 30
Hydraulic Gradient: -0.3
Time(yrs): 500
------------------------------------------------------------
1st Argument(Y1)is:                              2.9756
1st Error Function is:                           0.9999
2nd Argument(Y2)is:                              1.22525
2nd Error Function is:                           0.9173
Exit/Source Concentration Ratio  (C/Co)is:                     8E-05
------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 750
------------------------------------------------------------
1st Argument(Y1)is:                              2.78685
1st Error Function is:                           0.99979
2nd Argument(Y2)is:                              0.64312
2nd Error Function is:                           0.63658
Exit/Source Concentration Ratio  (C/Co)is:                     2.2E-04
------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 1000
------------------------------------------------------------
1st Argument(Y1)is:                              2.72291
1st Error Function is:                           0.99973
2nd Argument(Y2)is:                              0.24754
2nd Error Function is:                           0.27399
Exit/Source Concentration Ratio  (C/Co)is:                     3.7E-04
------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 2000
------------------------------------------------------------
1st Argument(Y1)is:                              2.80056
1st Error Function is:                           0.9998
2nd Argument(Y2)is:                              -0.70014
2nd Error Function is:                           0
Exit/Source Concentration Ratio  (C/Co)is:                     4.2E-04
------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 5000
------------------------------------------------------------
1st Argument(Y1)is:                              3.43176
1st Error Function is:                           0.99998
2nd Argument(Y2)is:                              -2.10334
2nd Error Function is:                           0
Exit/Source Concentration Ratio  (C/Co)is:                     3.3E-04
------------------------------------------------------------
Continue Calculations (y/n) ? n
```

$D = 0.102\ ft^2/yr\ (3 \times 10^{-6}\ cm^2/sec)$
$k = 0.025\ ft/yr\ (2.5 \times 10^{-8}\ cm/sec)$
$n = 30\%$
$X = 30\ ft.$



Full Logarithmic, 3 × 3 Cycles

Report Prepared for:

Wayne Disposal, Inc.

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

by

Donald H. Gray
Professor of Civil Engineering
The University of Michigan

Ann Arbor, Michigan

July 1983

SUMMARY

The possibility of leachate migration downward from the Allen Park Clay Mine/Landfill and contamination of an aquifer beneath were evaluated.

Analyses show that density differences between the leachate and groundwater will not cause a downward migration nor will they lead to a diffusion efflux from the site. A thick, uniform layer of silty clay beneath the site coupled with an upward hydraulic gradient effectively precludes the latter.

Comparison with results of salt water intrusion studies across clay aquitards having similar properties as the clay beneath the Allen Park site show that the solute (salt) will take at least 800 years to migrate across a clay barrier 30 feet thick under chemico-osmotic diffusion alone. A counter (or upward) hydraulic gradient will lengthen this breakthrough time even further.

There are insufficient amounts of organic compounds in the waste to affect the permeability of the clay. The probability of accelerated leachate migration through the underlying clay is not supported by the composition of the wastes and the nature of the clay nor by the findings of leachate permeability studies reported in the technical literature.

Under these circumstances any observed increases in contaminant levels of monitor wells in the aquifer underlying the site could more reasonably come from sources laterally upgradient from the site rather than the clay mine/landfill above the site.

TABLE OF CONTENTS

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

I. INTRODUCTION

The Ford Motor Company who operate the Allen Park Clay Mine/Landfill have recently petitioned to discontinue ground water monitoring of an aquifer located approximately 70 feet below existing grade at the site. The landfill is underlain by dense, lacustrine clay which behaves as an aquiclude or aquitard. At least 25 feet or more of residual clay thickness separates the bottom of the landfill from the underlying aquifer. The aquifer is under artesian pressure and exerts an upward hydrostatic pressure on the base of the clay aquitard equivalent to 80 feet of head. A general cross section or profile illustating these soil and hydrologic conditions at the site is shown in Figure 1.

Applicant maintains in his petition for discontinuance (EPA I.D. No. MIT 980568711) that monitoring is not necessary at the site because of a) the dense, uniform clay underlying the site which has a hydraulic permeability no greater than 6×10^{-8} cm/sec and b) the artesian pressure in the underlying aquifer which results in an upward hydraulic gradient across the overlying clay aquitard. Applicant claims that these site conditions will preclude the possibility of leachate migrating downwards out of the landfill and eventually contaminating the aquifer.

In response to this petition, the Wayne County Department of Public Health has raised several questions and concerns (letter form R.N. Ratz, Public Health Engineer, to B. Trethewey, Mining Properties Department, Ford Motor Company, 28 April 1983). The following concerns were raised in the letter:

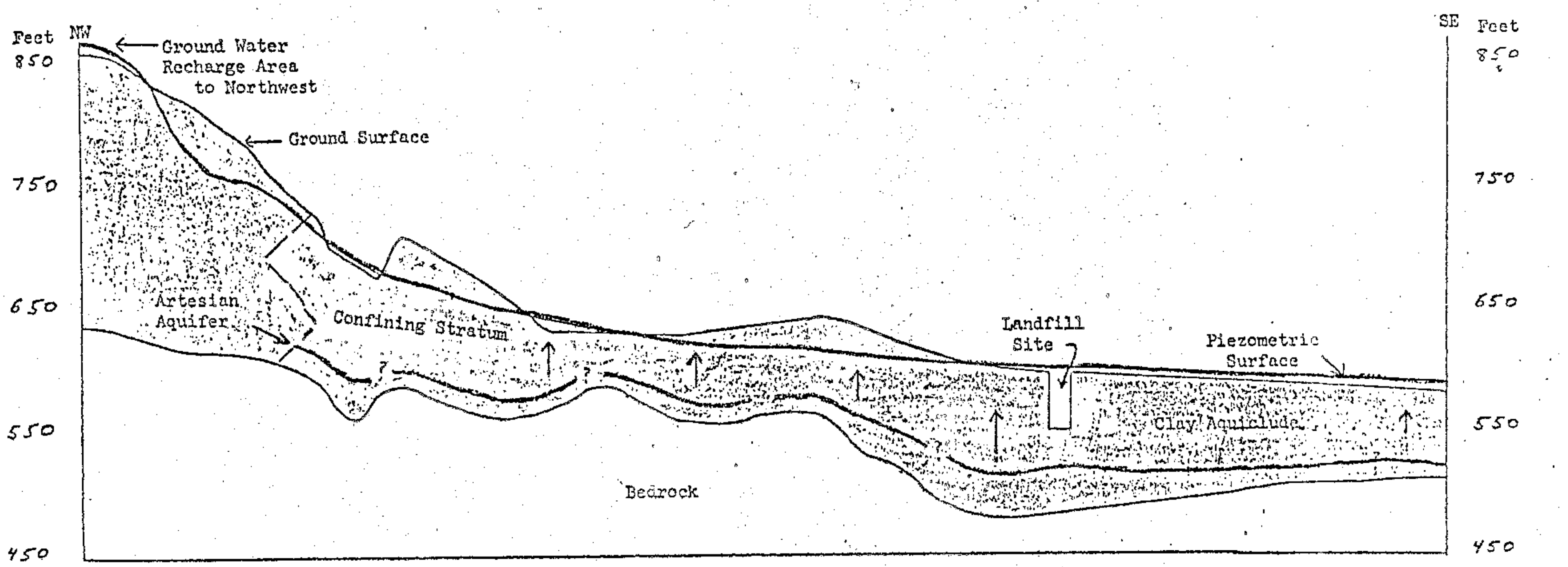
1. The petition/report fails to address the possibility of leachate migrating down due to differences in densities of the leachate and groundwater.

2. The petition/report does not indicate if there are any organic constituents in the leachate that may increase the clay's permeability and permit downward movement.

The purpose of the present report is to respond to the above stated concerns. Additional information about the geohydrology of the site, about past containment/migration studies, and about the likely nature of the leachate and its effect on clay permeability are evaluated herein to determine the danger of landfill leachate migrating downwards from the site and reaching the underlying aquifer.

NW - SE GENERALIZED CROSS SECTION

METROPOLITAN DETROIT AREA (ERIE - ST. CLAIR PLAIN)



SCALE

Vertical 1" = 100 Feet
Horizontal 1" = 2 Miles

Reference Map

USGS - Mich. Detroit District
Geology by W. H. Sherzer

Figure 1. Generalized cross-section through Allen Park Clay Mine/Landfill showing soil and hydrologic conditions.

II. THE INFLUENCE OF PERMEANT DENSITY ON LEACHATE MIGRATION ACROSS CLAY BARRIERS

A. GENERAL

Permeant density plays a direct and indirect role in flow phenomena in porous media. Permeant density can affect solvent or solution flow rates via its influence on hydraulic conductivity. This influence can be calculated and shown to be minor or insignificant compared to the more likely and important influence of permeant density on solute diffusion.

A newly introduced permeant with a high concentration of dissolved material (e.g., a leachate) will also have a higher density. This high concentration in turn will cause the solute to diffuse through a porous medium to regions of lower concentration. It is this manifestation or aspect of a density increase in the permeant that requires careful scrutiny and analysis. In other words, the role and influence of permeant density are more important to solute diffusion under concentration gradients as opposed to solvent (or solution) convection under hydraulic gradients.

The analyses that follow are offered in support of these claims.

B. INFLUENCE OF PERMEANT DENSITY INCREASE ON HYDRAULIC PERMEABILITY

Both the viscosity and unit weight of a permeant can influence the permeability of a soil to a particular permeant. The hydraulic conductivity is defined in this case as a flow velocity under a unit hydraulic gradient (the usual practice in civil engineering). The influence of permeant density and viscosity can be ascertained explicitly by defining another permeability, i.e., the "intrinsic" or "absolute" permeability

$$K = \frac{k\,\mu}{\gamma} \qquad (1)$$

where: k = hydraulic conductivity, cm/sec
K = intrinsic or absolute permeability, cm^2
γ = permeant density or unit weight, $dynes/cm^3$
μ = permeant viscosity, poise

The intrinsic permeability(K) is a property only of the solids or matrix through which the permeant passes. Accordingly, for a particular soil (i.e., given grain size distribution and soil structure) and in the absence of permeant-soil reactions, K should be a constant. The influence of a variation in viscosity and density of the permeant on the hydraulic conductivity can be determined from this fact and from a relationship derived from Equation 1, viz.,

$$k_2 = k_1 (\gamma_2/\gamma_1)\ (\mu_1/\mu_2) \qquad (2)$$

where: subscript 1 - initial conditions (grnd water)
subscript 2 - final conditions (leachate)

An increase in density of the permeant will apparently cause a higher permeability. But, this same increase in density can also result in an increase in viscosity which will reduce the permeability. Both influences together will tend to offset one another, and it is unlikely that a density increase in the permeant (leachate) will significantly affect hydraulic conductivity. Furthermore, even if viscous retardation is discounted, density increases are highly unlikely to significantly increase permeability in actual practice as the following example will show.

Assume the ground above an aquitard or clay barrier is flooded with a fairly concentrated brine solution, namely sea water. The density of sea water (with a TDS of 36,000 ppm) is 1.036 gm/cc at 4° C vs. the density of the present interstitial water (with an average TDS of 1550 ppm) which is 1.002 gm/cc. This leads to a density ratio of 1.034 which is equivalent to only a 3.4 per cent increase in hydraulic conductivity (discounting viscous retardation). Therefore, density has little effect on hydraulic conductivity despite the almost 20 fold increase in dissolved solids concentration. It is the influence of the latter change, i.e., the increase in dissolved solids concentration, that requires careful analysis in evaluating the effectiveness of a clay barrier in containing leachate migration in this case.

C. INFLUENCE OF PERMEANT DENSITY INCREASE ON SOLUTE DIFFUSION

1. Background

Dissolved solids or solutes in a permeant can be transported through soils under both hydraulic and concentration gradients. The former is referred to as "drag coupling" and the latter as "chemico-osmotic diffusion."[1] Both types of movement should be considered when evaluating the effectiveness of a clay barrier for preventing leachate migration.

Chemico-osmotic effects in fine grained soils have been examined in some detail by Olsen (1969) and Mitchell et al.(1973). The importance of chemico-osmotic diffusion increases in fine grained soils with low hydraulic conductivities. Studies commissioned by the State of California(1971) on salt intrusion problems in aquifer-aquitard systems have shown that as aquitards become clay rich and their permeabilities fall to levels on the order of .002 gpd/ft^2 or 10^{-7} cm/sec, the migration of solutes will be controlled by chemico-osmotic diffusion.

2. Flow of Solute under Combined Hydr. and Chem. Gradients

Equations can be derived which describe the flows of solute and solution in the pores of a sediment. The derivation of these equations and assumptions on which they are based are given by Mitchell *et al.* (1973). The one-dimensional, vertical, steady state flux of solute across a clay aquitard under a combined salt concentration (chemical) gradient and hydraulic gradient is given by the following relationship:

$$J_s = [(\gamma_w/TR)c_s k_{ch} + c_s k_h]\,\partial h/\partial z + [\,D + c_s k_{ch}]\,\partial c_s/\partial z \qquad (3)$$

where: J_s = salt flux across an aquitard, moles/sec/cm^2

$\partial h/\partial z$ = hydraulic gradient (dimensionless),

$\partial c_s/\partial z$ = solute concentration gradient, moles/cm^4

D = diffusion constant, cm^2/sec

R = gas constant, ergs/mole/°K

γ_w = density of water, dynes/cc

T = absolute temperature, °K

c_s = average salt concentration, moles/cc

k_h = hydraulic conductivity, cm/sec

k_{ch} = chemico-osmotic coupling coefficient, cm^5/mole/sec

Relative contributions to the salt or solute flux can be calculated from Equation 3. Movement of solute can occur by diffusion whether a hydraulic gradient is present or not. A superposed hydraulic gradient may retard or accelerate movement of solute depending on:

a) Relative magnitude and direction of the hydraulic and solute concentration gradients.

b) Values of the hydraulic conductivity and chemico-osmotic coupling coefficient.

Equation 3 only yields the steady state flux of solute under combined hydraulic and chemical gradients. Equations can also be derived that give the initial or time dependent solute fluxes and the time required for "breakthrough" or first appearance of increased solute concentration on the downstream side of the aquitard. This initial, non-steady state process is quite complicated. Examples have been worked out for aquitards of different thicknesses and composition by Mitchell *et al.* (1973).

One of the most important findings of these studies on salt flux across clay aquitards was the importance of aquitard thickness on breakthrough time. Because the initial movement is non-steady, the breakthrough time increases with the square of the thickness of the aquitard. Theoretical studies of salt water intrusion across aquitards (State of California, 1971) have shown that salt ions will

take up to 800 years to migrate across an aquitard 30 feet thick under chemico-osmotic diffusion alone. If the thickness is reduced to 10 feet, the breakthrough time decreases to only 80 years. The presence of an hydraulic gradient could either accelerate or retard this time depending on the relative magnitude and direction of this gradient and other factors cited previously (see Figure 3).

3. Likelihood of Solute Efflux Through Clay at Allen Park Site

Solutes will tend to migrate or diffuse downward from the landfill along a concentration gradient. On the other hand, this movement can be impeded or even arrested by the upward hydraulic gradient as a result of artesian pressure in the underlying aquifer. Static water levels in monitor wells around the landfill show that the piezometric surface is almost 10 feet above existing grade or ground surface elevation at the site (see Table 1). The net, steady state flux of solute, if any, can be determined under these conditions from the solute flow equation cited previously (Equation 3).

It is also pertinent to examine the results of a similar type of study commissioned by the State of California (1971). The latter study was designed to determine salt efflux rates and breakthrough times in an aquitard-aquifer system in the coastal ground water basin near Oxnard, California (see Figure 2). The problem posed in the California study was basically the same as the pre-sent one; namely, given a sudden increase in dissolved solids or solute concentration atop a clay barrier (or aquitard) how long before the salt migrated downward and reached an underlying aquifer and at what rates of efflux? The problem was compounded in the California example as a result of drawdown of the piezometric surface in the underlying aquifer which also caused a downward hydraulic gradient.

The two aquitards are quite similar in their important respects. Both are approximately the same thickness, have the same initial dissolved solids concentration, and are composed of clayey sediments with low hydraulic conductivities. The salient charateristics and parameters of these two aquitards are summarized and compared in Table 2. The main difference appears to be in their respective hydraulic conductivities--the Allen Park clay is an order-of-magnitude lower.

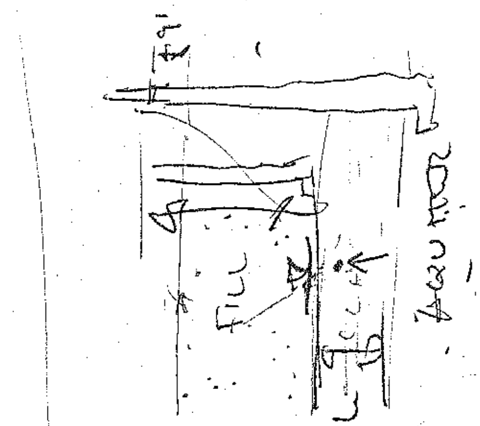
A dissolved solids concentration equal to that of sea water was assumed in the leachate overlying the Allen Park clay. Sea water is a good "worst case" choice because sodium ions have high diffusion mobilities and are not preferentially adsorbed on clay exchange sites as heavy

TABLE 1. ALLEN PARK CLAY MINE

MONITOR WELL - WATER LEVEL READINGS

Well Number	Ground Elevation, Ft.	Well Elevation(1) USGS	Ground Water(2) Elevation 11-4-81	Δ	Ground Water(3) Elevation 5-29-81	Ground Water(3) Elevation 3-26-81
2	595.1	600.76	600.67	5.6	600.44	600.21
5	595.7	605.92	605.09	9.4	604.62	604.49
7	594.1	597.35	591.01	-3.1	593.23	594.14
10	593.4	603.03	601.81	8.4	601.93	601.56
W-101	593.9	601.47	601.21	7.3		
W-102	591.3	600.81	603.22(4)	11.9		
W-103	593.9	605.06	603.52	9.6		
W-104	594.1	603.82	603.81	9.6		
W-105	594.5	604.08	603.86	9.4		

$\Delta_{AV} = 8.9$

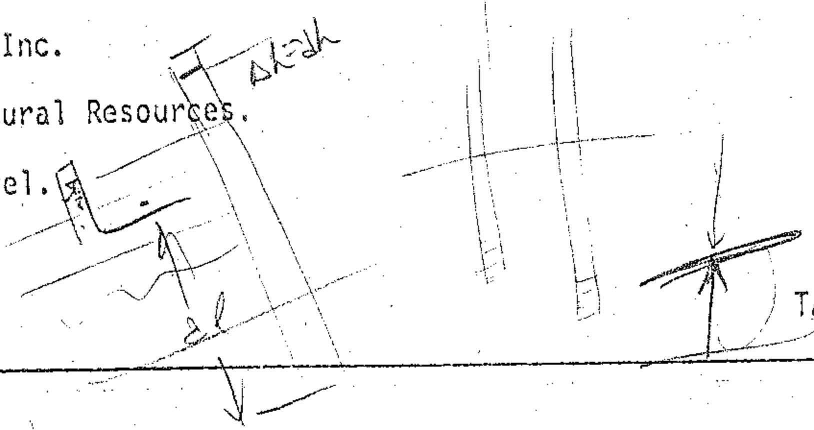


(1) Well Elevation is recorded as top of standpipe.

(2) Data Recorded by Michigan Testing Engineers, Inc.

(3) Data obtained from Michigan Department of Natural Resources.

(4) Well extended temporarily to obtain water level.



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27

TABLE 1

MICHIGAN TESTING ENGINEERS, INC.

TABLE 2. COMPARISON OF AQUITARD PROPERTIES AND SITE PARAMETERS

AQUITARD PROPERTY OR SITE PARAMETER	OXNARD CALIFORNIA	ALLEN PARK MICHIGAN
Composition	clayey silt & silty clays	silty clay
Thickness, ft	30	25 – 35
Ave. Water Content, %	24	20
Ave. Liquid Limit, %	31	28
Ave. Hydraulic Conduct, cm/sec	1×10^{-7}	2.6×10^{-8}
Hydraulic Gradient $= \frac{dh}{dl}$	0.33 – 1.0 (downward)	2.7 (upward)
Initial (interstitial) Pore Water Solute Conc, ppm	1800	1550
Final Solute Conc, ppm	36,000	36,000 (assumed)
Chemico-Osmotic Coupling Coefficient, cm^5/mole/sec	6.2×10^{-4}	6.2×10^{-4}

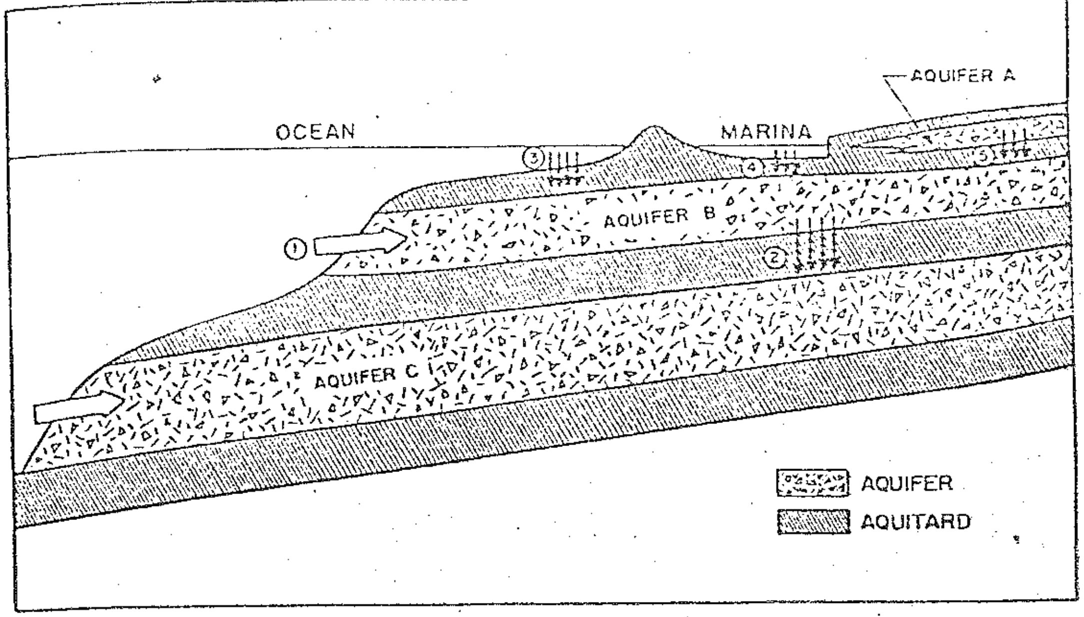

Figure 2. Generalized cross-section of multiple aquifer in a coastal basin. Salt flux across aquitard can occur as result of either salt water intrusion into aquifer (1,2) or salt water entering directly above aquitard in shallow coastal waters or marinas (3,4), or from salt contamination in near surface, perched aquifer (5).

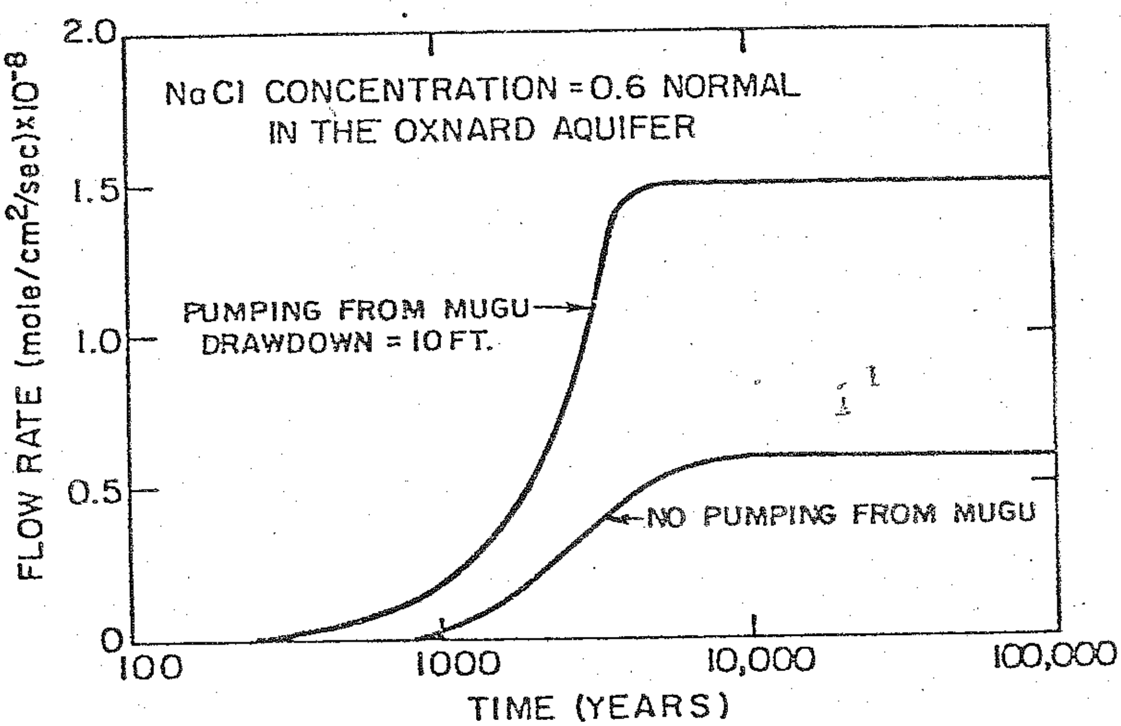

Figure 3. Solute efflux across aquitard into underlying aquifer as a result of salt water intrusion in overlying aquifer. Aquitard is 30 feet thick and has a hydraulic conductivity of 10^{-7} cm/sec. Pumping from lower (Mugu) aquifer superposes a 0.33 downward gradient on system.

metal ions would tend to be. The same chemico-osmotic coupling coefficient used in the California aquitard was also assumed applicable for the Allen Park clay. The value used is reasonable for the type of clay sediments present.

Results of the California study are presented in Figure 3 which shows the salt influx into the underlying aquifer as a function of time. Curves are presented for a no drawdown and 10-foot drawdown case (assuming the hydraulic gradient acts in the <u>same</u> direction as the salt concentration gradient). The horizontal portion of the two curves represents the steady state salt flux.

The main things to notice from this figure are the large breakthrough time (800 years) for the "no drawdown" case (i.e., in the absence of any hydraulic gradients) and the fact that in this aquitard the salt flux caused by drag coupling under a hydraulic gradient is larger. The steady state salt flux from the drag coupling under a combined 10-foot drawdown and salt concentration gradient is almost three times that from diffusion alone (no drawdown). <u>Hence, in the event the hydraulic gradient was reversed, there would be no breakthrough and no downward salt flux provided the upward gradient exceeded about 0.2.</u> In other words, under these conditions the two salt fluxes would be mutally opposed and exactly counterbalanced.

The relative contributions to steady state efflux in this example can be calculated with the aid of Equation 3. The following parameter values (taken from the study) were used in the calculation:

$$\partial h / \partial z \approx \Delta h / \Delta L = 10/30 = 0.33$$

$$\partial c / \partial z \approx (c_{s_2} - c_{s_1})/\Delta L = \frac{0.57 \times 10}{914} = 0.62 \times 10 \text{ moles/cm}^4$$

$$c_s = (c_{s_2} + c_{s_1})/2 = \frac{(0.60 - 0.03) \times 10}{2} = 0.32 \times 10 \text{ moles/cm}^3$$

$$D = 10^{-5} \text{ cm}^2/\text{sec}$$

$$R = 8.32 \times 10^7 \text{ ergs/mole/}^\circ\text{K}$$

$$T = 300\ ^\circ\text{K}$$

$$\gamma_w = 10^3 \text{ dynes/cc}$$

$$k_h = 10^{-7} \text{ cm/sec}$$

$$k_{ch} = 6.2 \times 10^{-4} \text{ cm}^5\text{/mole/sec}$$

Using these values the calculated contributions to steady state solute flux are respectively:

Drag Coupling: $J_{s_1} = [(\gamma_w/RT)c_s k_{ch} + c_s k_h] \partial h/\partial z$

$$= \left[\frac{10^3(2\times10^{-7})}{8.32\times10^7(.3\times10^{-3})} + 0.32\times10^{-3}(10^{-7})\right] 0.33$$

$$= 1.056 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{0.98 \times 10^{-8} \text{ moles/sec/ft}^2}$$

Chemico-Osmotic Diffusion:

$$J_{s_2} = [D + c_s k_{ch}] \partial c_s/\partial z$$

$$= [10^{-5} + 2\times10^{-7}] \, 0.62\times10^{-6}$$

$$= 0.63 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{0.58 \times 10^{-8} \text{ moles/sec/ft}^2}$$

The total salt flux is the sum of the contributions from drag coupling and chemico-osmotic diffusion or

$$J_s = J_{s_1} + J_{s_2}$$

$$= (0.98 + 0.58) \times10^{-8}$$

$$= \underline{1.56 \times 10^{-8} \text{ moles/sec/ft}^2}$$

These calculations are in agreement with the results shown in Figure 3 for steady state salt inflow under combined gradients. They also illustrate that the drag coupling contribution under a 10-foot drawdown (0.33 hydraulic gradient) exceeds the chemico-osmotic diffusion contribution.

In the case of the clay aquitard beneath the landfill at Allen Park, the average hydraulic conductivity is almost an order-of-magnitude lower (2.6×10^{-8} vs. 10^{-7} cm/sec). This will tend to decrease the drag coupling. On the other hand, this tendency will be more than offset by higher hydraulic gradients at this site. If the level of the leachate is kept at or close to the bottom of the landfill, then the gradient will approach 80/30 or 2.7. The drag coupling component of solute flux in this case will be

$$J_{s_1} = \left[\frac{10^3(2\times10^{-7})}{8.32\times10^7(.3\times10^{-3})} + 0.32\times10^{-3}(2.6\times10^{-8})\right] \times 2.7$$

$$= [0.008\times10^{-12} + 0.832\times10^{-11}] \times 2.7$$

$$= 2.25 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{2.09 \times 10^{-8} \text{ moles/sec/ft}}$$

This flux is greater than 3X the chemico-osmotic flux; and since it acts in the opposite direction, there will be no net downward flux of solute at the Allen Park site. The critical hydraulic gradient to maintain a zero net salt efflux is 0.8. This means that the groundwater table could rise to within 12 feet of present ground elevation (~595 ft) in the landfill and there would still be a sufficient upward hydraulic gradient (drag coupling effect) to completely counter solute efflux under chemico-osmotic diffusion (see summary below).

Position of Ground Water Table in the Landfill	Upward Hydraulic Gradient	Net, Steady State Solute Efflux Rate (moles/sec/ft^2)
At bottom	2.7	-1.51×10^{-8} (net influx)
12 feet from top	0.8	zero
At top	0.33	$+0.32 \times 10^{-8}$

These calculations are based on the existence of a static or piezometric head in the underlying aquifer approximately 9-10 feet above ground elevation (see Table 1).

Assumption of worst case conditions, namely, a rise in the groundwater table in the landfill to ground surface elevation, leads to a small, steady state efflux rate from chemico-osmotic diffusion. This occurs because the resulting hydraulic gradient (0.33) is no longer large enough to completely oppose the chemico-osmotic salt flux. The breakthrough times, however, would be so immense (1000's of years) that the steady state flux under these conditions is largely irrelevant.

It is important to note that the preceding calculations are also based on the following "worst case" assumptions:

1. A highly saline leachate with a concentration and composition equal to that of sea water.

2. No interaction between the solute and clay.

In actual practice, there would be some uptake and adsorption of solutes on the clay. This adsorption would attenuate or limit further solute concentrations in the leachate as it passed through the clay.

III. EFFECT OF LEACHATE CONSTITUENTS ON THE PERMEABILITY OF CLAY

A. GENERAL BACKGROUND

The possibility that leachate--either in the solvent or solute phase--might affect clay permeability and hence its containment integrity has been raised by a number of investigators (Anderson and Brown, 1981; Haxo, 1981; and Folkes, 1982). One of these studies has shown that concentrated organic liquids can increase clay permeability by several orders-of-magnitude (Anderson and Brown, 1981).

All of these studies were conducted in the laboratory with simulated leachates from particular types of wastes and under particular testing conditions. The danger of blindly applying these test results to a field situation have been noted recently by Gray and Stoll (1983). It is essential to ask the following before the results of these lab tests can be applied to a given field situation:

1. What was the nature of the leachate in the lab tests? What are the concentrations of various constituents in the leachate in the field as opposed to the lab tests? How relevant are the lab test results in the light of potentially large differences in leachate composition (lab vs. field)?

2. How did the leachate contact or interact with the clay in the lab tests? Was it forced through? If so, at what gradient? Is there any prospect that the leachate will be able to penetrate/permeate through the clay containment in the field in like manner? In other words are the necessary gradients and other conditions present to permit this to happen?

3. What was the failure or clay degradation process by which the apparent permeability increase occured in the lab tests? Was it by a) dissolution, b) syneresis, c) piping? Could these mechanisms reasonably occur in the field given the type, water content, and density of the in-situ clay plus the nature and concentration of organic and inorganic compounds in the leachate?

B. WASTE AND LEACHATE COMPOSITION AT THE ALLEN PARK CLAY MINE

The types, composition, and relative amounts of wastes placed in the Type II Solid Waste Landfill at Allen Park are shown in Tables 3 and 4. The results of typical E.P.T leachate tests on these wastes are shown in Table 5. The likely nature and composition of the landfill leachate can be estimated from this information. This estimate is adequate for purposes of evaluating the probable effect of the leachate on clay permeability.

TABLE 3. ALLEN PARK CLAY MINE - SOLID WASTE LANDFILL CONSTITUENTS

Fly Ash	-	50%
Blast Furnace Filter Cake	-	15%
Construction Debris - Sweepings - Clean-Up	-	14%
BOF Dust	-	6%
Foundry Sand	-	6%
Electric Furnace Dust	-	4.8%
Coal and Coke	-	3%
Coke Oven Decanter Tar Sludge	-	0.6%
Glass	-	0.5%
Wood Ash	-	0.5%
BOF Kish	-	0.3%
Wastewater Treatment Sludge	-	0.2%
Grinding Mud	-	0.1%

1

TABLE 5. ALLEN PARK CLAY MINE SOLID WASTES
TYPICAL E.P.T. LEACHATE TEST RESULTS (Mg/l)

Parameter	Blast Furnace Flue Dust	BOF Flue Dust	Blast Furnace Filter Cake	Foundry Sand	BOF Kish	Coke Breeze	Wastewater Treatment Sludge
Arsenic	0.04	0.02	< 0.1	0.03	0.1	< 0.1	.008
Barium	< 0.8	< 0.04	< 0.8	< 0.08	< 0.8	< 0.8	.45
Cadmium	0.01	0.03	< 0.08	< 0.005	< 0.005	< 0.005	.005
Chromium	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	.101
Lead	< 0.2	1.7	1.7	< 0.2	< 0.2	< 0.2	.025
Mercury	0.0007	< 0.01	< 0.2	< 0.2	< 0.2	< 0.2	.0005
Selenium	1.0	< 0.01	< 0.2	0.10	0.4	< 0.5	.008
Silver	< 0.1	< 0.01	< 0.01	< 0.1	< 0.1	< 0.1	.006

Compiled By [illegible]
March 1, 19[illegible]

The data in Tables 3 and 4 indicate that 50 per cent of the solid waste consists of relatively inert fly ash and that some 89 per cent of the wastes consist of materials that do not contain significant amounts of heavy metals (Zn, Pb, Cd) or organics known or suspected to be toxic such phenol and naphthalene (see Table 4). The coke oven decanter tar sludge is a possible source of organics (phenol and napthalene), but this waste comprises only 0.6 per cent of the total stream in the Type II Solid Waste landfill.

C. PROBABILITY OF ORGANICS IN LEACHATE AFFECTING CLAY PERMEABILITY AT ALLEN PARK SITE

Anderson and Brown (1981) found that several organic liquids, viz., aniline, acetone, ethylene glycol, heptane, and xylene, cause large increases in permeability of four compacted clay soils. Pure organic liquids were used in their study. One of the authors (Anderson, 1982) later emphasized that their results cannot be used to support claims that clay liners permeated by dilute organic liquids may be susceptible to large permeability increases.

Haxo (1981) reported results of up to 52 months of liner exposure to selected industrial wastes. He included several organic wastes, namely, aromatic oil, Oil pond 104, and a pesticide. The results of large permeameter tests on a compacted fine-grained soil and admixed materials are summarized in Table 6. Although a small amount of seepage passed through the compacted, fine-grained soil liner, no permeability increases were reported with any of the organic wastes.

On the basis of these studies and with the caveats noted at the beginning of this section in mind, it is possible to evaluate the likely effect of the landfill leachate on clay permeability at the Allen Park site.

1. Type II Solid Waste Landfill

As noted previously the existing landfill contains small quantities of coke oven decanter tar sludge which is a possible source of organics (phenol and naphthalene), but this waste comprises only 0.6 per cent of the total. Phenol and naphthalene are present in the tar component of this waste in concentrations estimated by Desha (1946) of 0.1 and 2.2 per cent by weight respectively. Accordingly, the amount of phenol and naphthalene present in the total waste stream are .006 and .013 per cent by weight respectively. These amounts constitute a very low fraction and they suggest that leachate from the total waste stream will tend to have very low concentrations of phenol and napthalene. Therefore, the organics in the leachate from the Type II Solid Waste landfill are quite unlikely to affect clay permeability.

TABLE 6. EFFECTS OF INDUSTRIAL WASTES ON SOIL AND ADMIX LINERS (from Haxo, 1981)

Liner material	Acidic waste (HNO_3, HF, HOAC)	Alkaline waste (spent caustic)	Lead (low lead gas washing)	Oily waste: Aromatic oil	Oily waste: Oil pond 104	Pesticide (weed killer)
Compacted fine-grained soil 305 mm thick	Not tested	Measurable rate of seepage $v_s = 10^{-10}-10^{-9}$ m/s, waste penetrated 3–5 cm after 30 months (*a*)		$k=1.8\times10^{-10}$ $k=2.4\times10^{-10}$ $k=2.6\times10^{-10}$ (tests on soil after 30 months)	†	†
Soil cement 100 mm thick	Not tested	No measurable seepage after 30 months				
Modified bentonite and sand (2 types) 127 mm thick	Not tested	Measurable seepage after 30 months, channelling of waste into bentonite (*b*)			Failed (waste seepage through liner)	‡
Hydraulic asphalt concrete 64 mm thick	Failed	Satisfactory	Waste stains below liner asphalt mushy	Not tested	Not tested	Satisfactory
Spray-on asphalt and fabric 8 mm thick	Not tested	Satisfactory	Waste stains below liner	Not tested	Not tested	Satisfactory

*From data presented by Haxo (1981).
†Same as (*a*).
‡Same as (*b*).

2. <u>Type I Hazardous Waste Landfill</u>

In the future the decanter tar sludge will be placed in a separate landfill that will be upgraded to accept hazardous wastes. This action will increase the relative proportion of organics (phenol and naphthalene) in the waste stream. Leachate tests run on <u>pure</u> samples of decanter tar sludge using a distilled water extraction procedure (Calspan, 1977) have produced phenol concentrations of approximately 500 ppm. Even this concentration is far removed from the very high concentrations of organic solvents used by Anderson and Brown (1981) in their permeability tests on different clays. Accordingly, organics in the leachate from the Type I Hazardous Waste landfill are also unlikely to affect clay permeability.

<u>In summary:</u> It does not appear likely nor reasonable that organics present in the wastes at the Allen Park Clay Mine/Landfill will cause a permeability increase given their low concentration and the absence of any substantiation in the published technical literature for such an increase under these conditions.

IV. CONCLUSIONS

(1). There appears to be very little likelihood of leachate migrating downward from the Allen Park Clay Mine/Landfill and contaminating the aquifer beneath the clay.

(2). A density difference between the leachate and groundwater will have little or no influence on hydraulic permeability or downward migration nor will it lead to diffusion efflux of solutes. A thick, uniform bed of silty clay beneath the site coupled with an upward hydraulic gradient precludes the latter. Calculations and analyses are provided herein to support this finding.

(3). Comparison with results of salt water intrusion studies across clay aquitards having similar properties as the clay beneath the Allen Park Clay Mine site show that the solute (salt) will take at least 800 years to migrate across a clay barrier 30 feet thick under chemico-osmotic gradients alone. A counter (or upward) hydraulic gradient will increase this breakthrough time even more.

(4). The waste and its leachate are unlikely to increase the permeability of the underlying clay. This claim is reasonable in view of the low concentrations of organics in the total waste stream and in the light of the findings and caveats of permeability/exposure tests with organic permeants reported in the technical literature. This conclusion applies to both the existing Type II Solid Waste landfill and a proposed Type I Hazardous Waste landfill that will accept the coke oven decanter tar sludge.

chemical analysis ?

(5). The composition of the waste and underlying clay do not suggest properties or combination of properties that could lead to a containment failure caused by such processes as piping, acid/base dissolution, or syneresis.

(6). Under these circumstances any observed increase in contaminant levels of monitor wells in the aquifer underlying the site could just as well come from other sources laterally upgradient from the site rather than from the clay mine/landfill above the site.

(7). These findings and conclusions support the basis of applicant's petition for discontinuing further monitoring of the wells penetrating the aquifer beneath the site.

V. REFERENCES CITED

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October 11, 1984

Mr. David Miller
Ford Motor Company - Steel Division
P.O. Box 1639
Dearborn, Michigan 48121

Dear Mr. Miller:

This letter is to summarize the October 2, 1984 meeting held at the Detroit district office between Ford, your consultant, and members of this department.

Compatibility testing between the natural clay liner and the site leachate is needed. The department recommends the use of leachate from Wayne Disposal Inc. for this testing since it would substantially reduce or eliminate the need for further testing of this type in the event that you seek approval to take additional waste types in the future. It was agreed that this testing will utilize a flexible wall parameter. The leachate must be tested to determine whether it contains the concentrations of chemicals in the leachate found now at your site plus those anticipated in the future. If it doesn't, the Wayne Disposal leachate used for the test will have to be modified by adding the necessary additional compounds. The impact of the Wayne Disposal leachate, modified as necessary, will be compared to similar testing using water.

Your consultant has provided theoretical calculations which indicate that it is impossible for contaminants to pollute the artesian aquifer which underlies the site. These calculations have assumed an upward gradient throughout the site's clay unit. It was agreed that this assumption will be examined by the use of site specific data. Three piezometer nests, each containing a minimum of three piezometers, will be installed within this unit to measure the distribution of the pressure head from the artesian aquifer. A flow net will then be constructed from this data which will substantiate or refute this assumption. Should this assumption be shown to be correct, groundwater monitoring will be focused on the shallow, surficial sand aquifer.

The shallow, surficial sand aquifer apparently only exists along the eastern end of the hazardous waste cells. It was agreed that monitoring of this aquifer is needed. However, due to the potential problem of possible recharge of the unit by the external drainage ditch, installation of a vertical detection system (sand or gravel sandwiched between clay walls) was discussed. A well can then be placed within the sandwiched permeable material for performance monitoring. Because wastes are presently near the sand unit, the department requests that this system be constructed soon, so as to develop background data. You should contact us in the near future so that we can reach agreement on appropriate design concepts. Once agreement is reached, you would be expected to prepare detailed engineering plans for our review and approval.

There was discussion of whether a gas venting system will be needed upon placement of the final cover. It was agreed that a system would not be required at this time. However, if significant gas generation is ever noted or if a change in the types of waste received ever suggests gas generation would be likely to occur, a venting system will be required.

Because of the need for you to satisfy RCRA Part B requirements in addition to MDNR requirements, it was agreed that we would meet with you at your request in the near future and discuss your proposals.

Sincerely,

TMc

Terrance J. McNiel, Geologist
Technical Services Section
Hazardous Waste Division
517-373-2730

tkr

cc: J. Bohunsky/C & E File
Okwumabua/Aubuchon
A. Howard, HWD
J. Amber, Ford - S32COS
C. Riley, HWD

1704 Morton Street
Ann Arbor, Michigan
48104

4 October1983

Ms. Jan Look
People's Action League, Inc.
P.O. Box 37
Eagle, MI 48822

RE: Granger Landfill, Clay Slurry Walls

Dear Ms. Look:

I have investigated further the problem of leachate leakage across clay slurry cut-off walls. My analyses show that the clay wall design proposed for the Granger landfill will not adequately impede the diffusion of leachate solutes. According to my calculations, breakthrough times for non-reactive solutes will be ten years or less, even in the presence of counter hydraulic gradients as high as unity.

The analyses were carried out using a computer program (*CLAYWALL*) that can be used to calculate solute transport across a clay barrier under combined diffusion and advection (hydraulic flow). The program computes the exit/source concentration ratio (C/Co) as a function of the wall or barrier thickness (X) and elapsed time (t). The following values for input data were used in the analyses:

Diffusion Coefficient = 0.102 ft^2/yr (based on measured values for sand-bentonite mixes)
Permeability = 0.1 ft/yr

Wall Thickness = 3 ft

Porosity = 25 %

Hydraulic Gradient = -0.02, -0.05, -0.2, -1.0

With the exception of the diffusion coefficent, these are the same values used in the diffusion analysis in the D'Appolonia report (Clay slurry Cut Off Wall, Appendix D). The value of the diffusion coefficient used in my analysis is based on actual, measured values[1] as opposed to assumed values used in the D'Appolonia report.

---

[1] Gillham,R.W. and Cherry,J.A.(1982). "Predictability of Solute Transport in Diffusion-Controlled Hydrogeologic Regimes, Proceedings, Symposium on Low Level Waste Disposal, Oakridge Natl. Laboratory, NuReg/CP-0028, Conf-820911, Vol 3, pp.379-410

The results of my analyses are shown in the attached graph. Breakthrough times (t_b) are indicated on the graph and are also summarized in the table below. Breakthrough time is defined as the time required for the exit concentration to reach a particular fraction or percent (say 1 %) of the source concentration.

Hydraulic Gradient	Breakthrough Time, t_b - yrs	
	C/Co = .001	C/Co = 0.1
-0.02	4.4	6.5
-0.05	4.5	7.1
-0.2	5.3	10.0
-1.0	10.0	-

These results indicate that leachate solutes will emerge on the other side of the clay slurry wall in a relatively short time ($\leqslant$ 10 yrs) inspite of a counter hydraulic gradient!

Admittedly, these analyses are worst case scenarios insofar as solute reactivity is concerned. Partioning or adsorption of solutes on the wall solids would retard diffusion flux and increase breakthrough times. On the other hand, failure to maintain a counter hydraulic flow into the landfill (e.g., as a result of plugging or failure in the interior leachate collection lines) would shorten breakthrough times.

The effectiveness of the clay walls as adequate diffusion barriers has not been demonstrated to date. No satisfactory data nor analyses have been presented (by Granger or his consultants) to show that there will be sufficient retardation of solutes in the clay walls to limit or impede diffusion to acceptable levels.

Sincerely,

Donald H Gray

Donald H. Gray
Professor of Civil Engineering

cc D. Montgomery, MDNR
P. Steketee

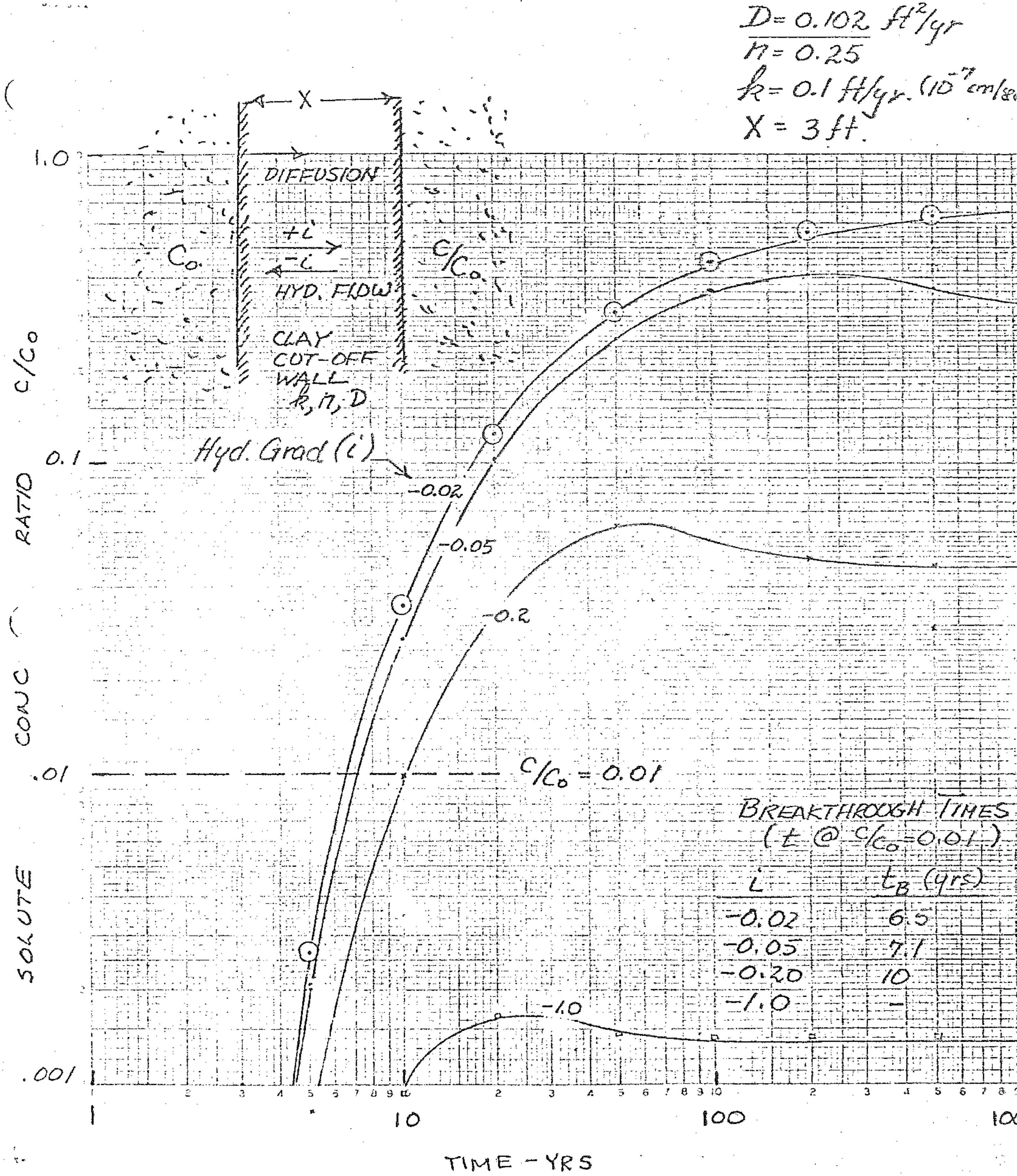


FIG. 2 SOLUTE TRANSPORT ACROSS CLAY SLURRY CUT-OFF WALL

#2

```
run
Porosity: 0.25
Permeability(ft/yr): 0.1
Diffusion Coef(ft /yr): 0.102
Wall Thickness: 3
Hydraulic Gradient: -0.02
Time(yrs): 3
---------------------------------------------------------------
1st Argument(Y1)is:                              2.73332
1st Error Function is:                           0.99974
2nd Argument(Y2)is:                              2.68994
2nd Error Function is:                           0.99969
Exit/Source Concentration Ratio  (C/Co)is:                        2.5E-04
---------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 5
---------------------------------------------------------------
1st Argument(Y1)is:                              2.12843
1st Error Function is:                           0.99693
2nd Argument(Y2)is:                              2.07241
2nd Error Function is:                           0.99616
Exit/Source Concentration Ratio  (C/Co)is:                        3.05E-03
---------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 10
---------------------------------------------------------------
1st Argument(Y1)is:                              1.52483
1st Error Function is:                           0.96914
2nd Argument(Y2)is:                              1.44562
2nd Error Function is:                           0.95942
Exit/Source Concentration Ratio  (C/Co)is:                        0.03147
---------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 20
---------------------------------------------------------------
1st Argument(Y1)is:                              1.10622
1st Error Function is:                           0.88255
2nd Argument(Y2)is:                              0.9942
2nd Error Function is:                           0.84025
Exit/Source Concentration Ratio  (C/Co)is:                        0.12185
---------------------------------------------------------------
Continue Calculations (y/n) ? y

Time(yrs): 50
---------------------------------------------------------------
1st Argument(Y1)is:                              0.75277
1st Error Function is:                           0.71247
2nd Argument(Y2)is:                              0.57565
2nd Error Function is:                           0.58427
Exit/Source Concentration Ratio  (C/Co)is:                        0.30805
---------------------------------------------------------------
Continue Calculations (y/n) ? n
```

JULY 1983 REPORT

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

1704 Morton Street
Ann Arbor, Michigan
48104

25 September 1983

Mr. Mark Young
Wayne Disposal Company
P.O. Box 5187
Dearborn, MI 48128

RE: Allen Park Clay Mine/Landfill

Dear Mark:

I recently wrote a computer program (*CLAYWALL*) that can be used to calculate solute transport across a clay barrier under combined diffusion and advection (hydraulic flow). The program computes the exit/source concentration ratio (C/Co) as a function of elapsed time (t) on the downstream side of a clay wall or barrier of thickness (X).

The program was written with a clay slurry cut-off wall in mind, but is general enough that it can be used with any clay layer or barrier. The input parameters to the program are:

- D_e = efffective diffusion coefficient, ft^2/yr
- K = hydraulic permeability, ft/yr
- X = thickness of wall or barrier, ft
- P = porosity
- I = hydraulic gradient...(+) if same direction, (-) if opposite direction to solute concentration gradient
- t = elapsed time, yrs

The program is based on the solution to the equation that describes one-dimensional solute transport in a saturated porous medium under both hydraulic and solute concentration gradients. This equation has the following form:

C/Co = 0.5[erfc((X-vt)/sqr(4DeK)) + exp(vX/D) erfc((X+vt)/sqr(4DeK))]

where: v = ave seepage velocity = (KI/P)

The solution assumes the following conditions:

1. Saturated, one-dimensional flow.
2. No reaction between solutes and porous medium. Chloride typically behaves this way.

3. Diffusion controlled, i.e., the pore water velocity is so low that mechanical mixing is negligible and the dispersion is equal to the effective diffusion coeffficient. (this condition is satisfied when K < 1.0E-07.

I ran the program using data for the silty clay layer underlying the Allen Park ClayMine/Landfill. The following values for the input data were used:

D = 0.102 ft^2/yr (6.3E-06 cm^2/sec)
(published value for clay tills)
K = 0.025 ft/yr (2.5E-08 cm/sec)
X = 30 ft
P = 30 %
I = -0.1,-0.3, and -1.0

The results of the analysis are shown in the attached graph. At a counter hydraulic gradient of -0.3 the exit/source solute concentration ratio does not exceed 0.0001 until 700 years have elapsed. You may recall that a counter hydraulic gradient of -0.3 occurs when the leachate is allowed to rise in the landfill to the ground surface...a worst case scenario. For larger (negative) counter hydraulic gradients the ratios become even smaller. In fact for I < -0.5 (i.e., counter hydraulic gradients larger than 0.5) the ratio C/Co is less than 1.0E-05 at all elapsed times.

These results confirm the findings of my earlier report which were based largely on analogy to solute transport studies in clay aquitards. The present findings are based on analysis of actual soil and site parameters. Keep in mind, also, that the analysis is still quite conservative because it neglects possible adsorption (reaction) of solutes with the clay.

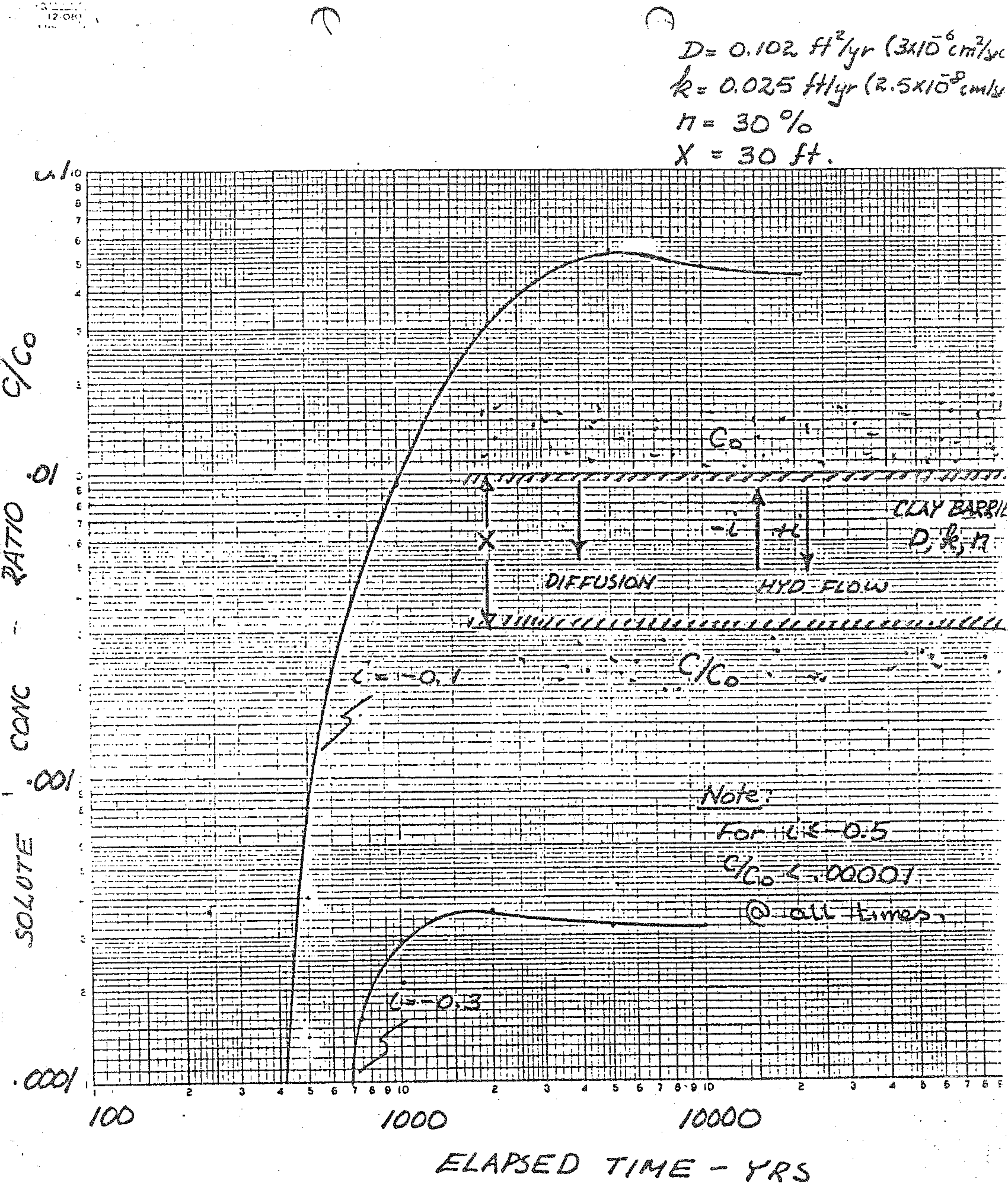
A copy of the computer program and typical output are enclosed. It is written in BASIC and is designed to be run on a personal computer. If you have any questions about the analysis, please feel free to contact me.

Sincerely,

Donald H. Gray

Donald H. Gray
Professor of Civil Engineering

Encl



Full Logarithmic, 3 × 3 Cycles

```
run
Porosity: 0.3
Permeability(ft/yr): .025
Diffusion Coef(ft /yr): 0.102
Wall Thickness: 30
Hydraulic Gradient: -0.3
Time(yrs): 500
-----------------------------------------------------------------
1st Argument(Y1)is:                                  2.9756
1st Error Function is:                               0.9999
2nd Argument(Y2)is:                                  1.22525
2nd Error Function is:                               0.9173
Exit/Source Concentration Ratio  (C/Co)is:                              8E-05
------------------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 750
-----------------------------------------------------------------
1st Argument(Y1)is:                                  2.78685
1st Error Function is:                               0.99979
2nd Argument(Y2)is:                                  0.64312
2nd Error Function is:                               0.63658
Exit/Source Concentration Ratio  (C/Co)is:                              2.2E-04
------------------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 1000
-----------------------------------------------------------------
1st Argument(Y1)is:                                  2.72291
1st Error Function is:                               0.99973
2nd Argument(Y2)is:                                  0.24754
2nd Error Function is:                               0.27399
Exit/Source Concentration Ratio  (C/Co)is:                              3.7E-04
------------------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 2000
-----------------------------------------------------------------
1st Argument(Y1)is:                                  2.80056
1st Error Function is:                               0.9998
2nd Argument(Y2)is:                                  -0.70014
2nd Error Function is:                               0
Exit/Source Concentration Ratio  (C/Co)is:                              4.2E-04
------------------------------------------------------------------
Continue Calculations (y/n) ? y


Time(yrs): 5000
-----------------------------------------------------------------
1st Argument(Y1)is:                                  3.43176
1st Error Function is:                               0.99998
2nd Argument(Y2)is:                                  -2.10334
2nd Error Function is:                               0
Exit/Source Concentration Ratio  (C/Co)is:                              3.3E-04
------------------------------------------------------------------
Continue Calculations (y/n) ? n
```

Report Prepared for:

Wayne Disposal, Inc.

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

by

Donald H. Gray
Professor of Civil Engineering
The University of Michigan

Ann Arbor, Michigan

July 1983

SUMMARY

The possibility of leachate migration downward from the Allen Park Clay Mine/Landfill and contamination of an aquifer beneath were evaluated.

Analyses show that density differences between the leachate and groundwater will not cause a downward migration nor will they lead to a diffusion efflux from the site. A thick, uniform layer of silty clay beneath the site coupled with an upward hydraulic gradient effectively precludes the latter.

Comparison with results of salt water intrusion studies across clay aquitards having similar properties as the clay beneath the Allen Park site show that the solute (salt) will take at least 800 years to migrate across a clay barrier 30 feet thick under chemico-osmotic diffusion alone. A counter (or upward) hydraulic gradient will lengthen this breakthrough time even further.

There are insufficient amounts of organic compounds in the waste to affect the permeability of the clay. The probability of accelerated leachate migration through the underlying clay is not supported by the composition of the wastes and the nature of the clay nor by the findings of leachate permeability studies reported in the technical literature.

Under these circumstances any observed increases in contaminant levels of monitor wells in the aquifer underlying the site could more reasonably come from sources laterally upgradient from the site rather than the clay mine/landfill above the site.

TABLE OF CONTENTS

CONTAINMENT INTEGRITY OF ALLEN PARK CLAY MINE/LANDFILL

I. INTRODUCTION

The Ford Motor Company who operate the Allen Park Clay Mine/Landfill have recently petitioned to discontinue ground water monitoring of an aquifer located approximately 70 feet below existing grade at the site. The landfill is underlain by dense, lacustrine clay which behaves as an aquiclude or aquitard. At least 25 feet or more of residual clay thickness separates the bottom of the landfill from the underlying aquifer. The aquifer is under artesian pressure and exerts an upward hydrostatic pressure on the base of the clay aquitard equivalent to 80 feet of head. A general cross section or profile illustating these soil and hydrologic conditions at the site is shown in Figure 1.

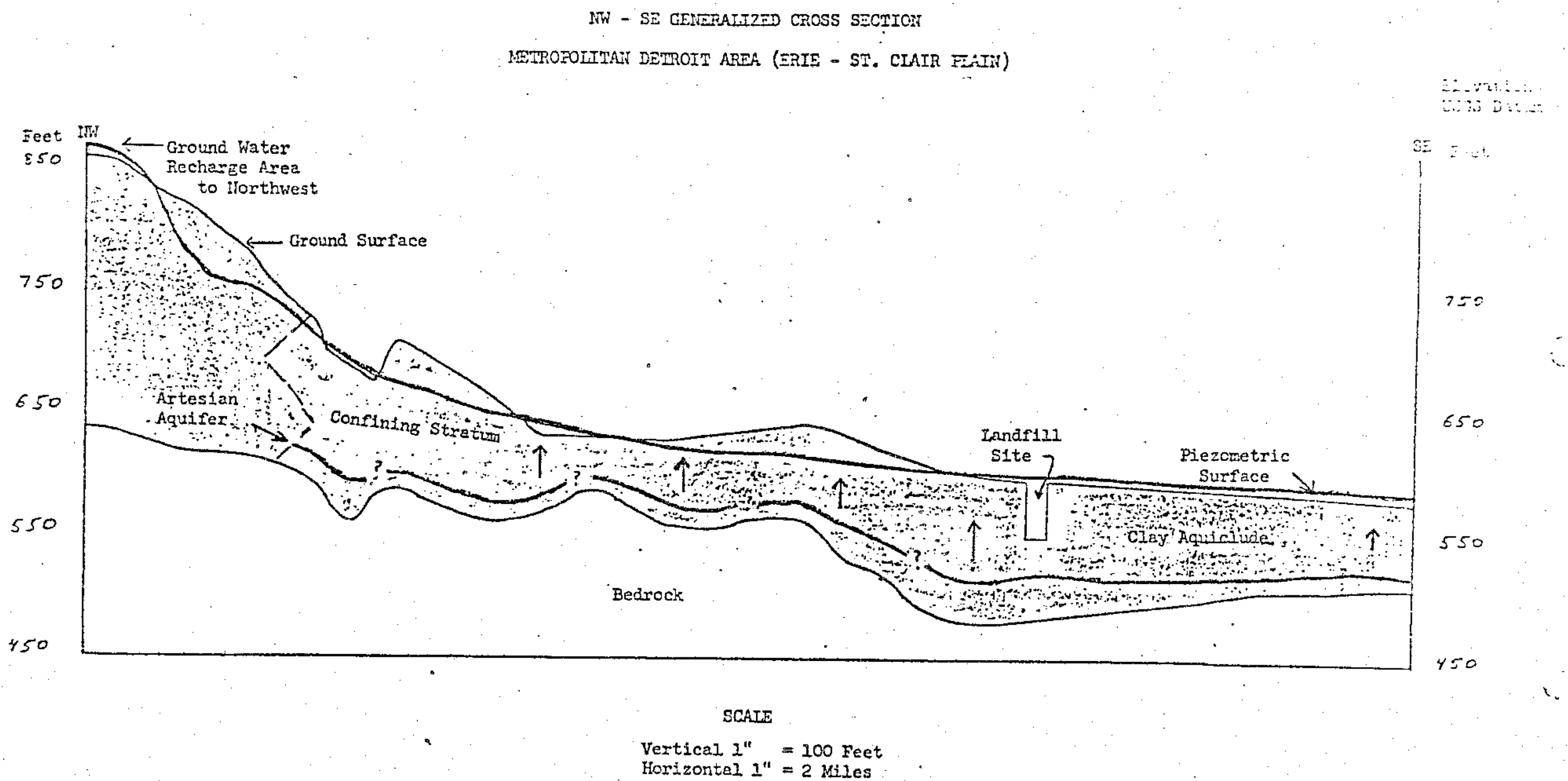
Applicant maintains in his petition for discontinuance (EPA I.D. No. MIT 980568711) that monitoring is not necessary at the site because of a) the dense, uniform clay underlying the site which has a hydraulic permeability no greater than 6×10^{-8} cm/sec and b) the artesian pressure in the underlying aquifer which results in an upward hydraulic gradient across the overlying clay aquitard. Applicant claims that these site conditions will preclude the possibility of leachate migrating downwards out of the landfill and eventually contaminating the aquifer.

In response to this petition, the Wayne County Department of Public Health has raised several questions and concerns (letter form R.N. Ratz, Public Health Engineer, to B. Trethewey, Mining Properties Department, Ford Motor Company, 28 April 1983). The following concerns were raised in the letter:

1. The petition/report fails to address the possibility of leachate migrating down due to differences in densities of the leachate and groundwater.

2. The petition/report does not indicate if there are any organic constituents in the leachate that may increase the clay's permeability and permit downward movement.

The purpose of the present report is to respond to the above stated concerns. Additional information about the geohydrology of the site, about past containment/migration studies, and about the likely nature of the leachate and its effect on clay permeability are evaluated herein to determine the danger of landfill leachate migrating downwards from the site and reaching the underlying aquifer.



Reference Map

USGS - Mich. Detroit District
Geology by W. H. Sherzer

Figure 1. Generalized cross-section through Allen Park Clay Mine/Landfill showing soil and hydrologic conditions.

II. THE INFLUENCE OF PERMEANT DENSITY ON LEACHATE MIGRATION ACROSS CLAY BARRIERS

A. GENERAL

Permeant density plays a direct and indirect role in flow phenomena in porous media. Permeant density can affect solvent or solution flow rates via its influence on hydraulic conductivity. This influence can be calculated and shown to be minor or insignificant compared to the more likely and important influence of permeant density on solute diffusion.

A newly introduced permeant with a high concentration of dissolved material (e.g., a leachate) will also have a higher density. This high concentration in turn will cause the solute to diffuse through a porous medium to regions of lower concentration. It is this manifestation or aspect of a density increase in the permeant that requires careful scrutiny and analysis. In other words, the role and influence of permeant density are more important to solute diffusion under concentration gradients as opposed to solvent (or solution) convection under hydraulic gradients.

The analyses that follow are offered in support of these claims.

B. INFLUENCE OF PERMEANT DENSITY INCREASE ON HYDRAULIC PERMEABILITY

Both the viscosity and unit weight of a permeant can influence the permeability of a soil to a particular permeant. The hydraulic conductivity is defined in this case as a flow velocity under a unit hydraulic gradient (the usual practice in civil engineering). The influence of permeant density and viscosity can be ascertained explicitly by defining another permeability, i.e., the "intrinsic" or "absolute" permeability

$$K = \frac{k\,\mu}{\gamma} \qquad (1)$$

where: k = hydraulic conductivity, cm/sec
K = intrinsic or absolute permeability, cm^2
γ = permeant density or unit weight, $dynes/cm^3$
μ = permeant viscosity, poise

The intrinsic permeability(K) is a property only of the solids or matrix through which the permeant passes. Accordingly, for a particular soil (i.e., given grain size distribution and soil structure) and in the absence of permeant-soil reactions, K should be a constant. The influence of a variation in viscosity and density of the permeant on the hydraulic conductivity can be determined from this fact and from a relationship derived from Equation 1, viz.,

$$k_2 = k_1 (\gamma_2/\gamma_1)(\mu_1/\mu_2) \qquad (2)$$

where: subscript 1 - initial conditions (grnd water)
subscript 2 - final conditions (leachate)

An increase in density of the permeant will apparently cause a higher permeability. But, this same increase in density can also result in an increase in viscosity which will reduce the permeability. Both influences together will tend to offset one another, and it is unlikely that a density increase in the permeant (leachate) will significantly affect hydraulic conductivity. Furthermore, even if viscous retardation is discounted, density increases are highly unlikely to significantly increase permeability in actual practice as the following example will show.

Assume the ground above an aquitard or clay barrier is flooded with a fairly concentrated brine solution, namely sea water. The density of sea water (with a TDS of 36,000 ppm) is 1.036 gm/cc at 4° C vs. the density of the present interstitial water (with an average TDS of 1550 ppm) which is 1.002 gm/cc. This leads to a density ratio of 1.034 which is equivalent to only a 3.4 per cent increase in hydraulic conductivity (discounting viscous retardation). Therefore, density has little effect on hydraulic conductivity despite the almost 20 fold increase in dissolved solids concentration. It is the influence of the latter change, i.e., the increase in dissolved solids concentration, that requires careful analysis in evaluating the effectiveness of a clay barrier in containing leachate migration in this case.

C. INFLUENCE OF PERMEANT DENSITY INCREASE ON SOLUTE DIFFUSION

1. Background

Dissolved solids or solutes in a permeant can be transported through soils under both hydraulic and concentration gradients. The former is referred to as "drag coupling" and the latter as "chemico-osmotic diffusion." Both types of movement should be considered when evaluating the effectiveness of a clay barrier for preventing leachate migration.

Chemico-osmotic effects in fine grained soils have been examined in some detail by Olsen (1969) and Mitchell et al.(1973). The importance of chemico-osmotic diffusion increases in fine grained soils wilth low hydraulic conductivities. Studies commissioned by the State of California(1971) on salt intrusion problems in aquifer-aquitard systems have shown that as aquitards become clay rich and their permeabilities fall to levels on the order of .002 gpd/ft^2 or 10^{-7} cm/sec, the migration of solutes will be controlled by chemico-osmotic diffusion.

2. Flow of Solute under Combined Hydr. and Chem. Gradients

Equations can be derived which describe the flows of solute and solution in the pores of a sediment. The derivation of these equations and assumptions on which they are based are given by Mitchell et al.(1973). The one-dimensional, vertical, steady state flux of solute across a clay aquitard under a combined salt concentration(chemical) gradient and hydraulic gradient is given by the following relationship:

$$J_s = [(\gamma_w/TR)c_s k_{ch} + c_s k_h]\,\partial h/\partial z + [D + c_s k_{ch}]\,\partial c_s/\partial z \qquad (3)$$

where: J_s = salt flux across an aquitard, moles/sec/cm^2
$\partial h/\partial z$ = hydraulic gradient (dimensionless)
$\partial c_s/\partial z$ = solute concentration gradient, moles/cm^4
D = diffusion constant, cm^2/sec
R = gas constant, ergs/mole/°K
γ_w = density of water, dynes/cc
T = absolute temperature, °K
c_s = average salt concentration, moles/cc
k_h = hydraulic conductivity, cm/sec
k_{ch} = chemico-osmotic coupling coefficient, cm^5/mole/sec

Relative contributions to the salt or solute flux can be calculated from Equation 3. Movement of solute can occur by diffusion whether a hydraulic gradient is present or not. A superposed hydraulic gradient may retard or accelerate movement of solute depending on:

a) Relative magnitude and direction of the hydraulic and solute concentration gradients.

b) Values of the hydraulic conductivity and chemico-osmotic coupling coefficient.

Equation 3 only yields the steady state flux of solute under combined hydraulic and chemical gradients. Equations can also be derived that give the initial or time dependent solute fluxes and the time required for "breakthrough" or first appearance of increased solute concentration on the downstream side of the aquitard. This initial, non-steady state process is quite complicated. Examples have been worked out for aquitards of different thicknesses and composition by Mitchell et al.(1973).

One of the most important findings of these studies on salt flux across clay aquitards was the importance of aquitard thickness on breakthrough time. Because the initial movement is non-steady, the breakthrough time increases with the square of the thickness of the aquitard. Theoretical studies of salt water intrusion across aquitards (State of California, 1971) have shown that salt ions will

take up to 800 years to migrate across an aquitard 30 feet thick under chemico-osmotic diffusion alone. If the thickness is reduced to 10 feet, the breakthrough time decreases to only 80 years. The presence of an hydraulic gradient could either accelerate or retard this time depending on the relative magnitude and direction of this gradient and other factors cited previously (see Figure 3).

3. Likelihood of Solute Efflux Through Clay at Allen Park Site

Solutes will tend to migrate or diffuse downward from the landfill along a concentration gradient. On the other hand, this movement can be impeded or even arrested by the upward hydraulic gradient as a result of artesian pressure in the underlying aquifer. Static water levels in monitor wells around the landfill show that the piezometric surface is almost 10 feet above existing grade or ground surface elevation at the site (see Table 1). The net, steady state flux of solute, if any, can be determined under these conditions from the solute flow equation cited previously (Equation 3).

It is also pertinent to examine the results of a similar type of study commissioned by the State of California (1971). The latter study was designed to determine salt efflux rates and breakthrough times in an aquitard-aquifer system in the coastal ground water basin near Oxnard, California (see Figure 2). The problem posed in the California study was basically the same as the pre-sent one; namely, given a sudden increase in dissolved solids or solute concentration atop a clay barrier (or aquitard) how long before the salt migrated downward and reached an underlying aquifer and at what rates of efflux? The problem was compounded in the California example as a result of drawdown of the piezometric surface in the underlying aquifer which also caused a downward hydraulic gradient.

The two aquitards are quite similar in their important respects. Both are approximately the same thickness, have the same initial dissolved solids concentration, and are composed of clayey sediments with low hydraulic conductivities. The salient charateristics and parameters of these two aquitards are summarized and compared in Table 2. The main difference appears to be in their respective hydraulic conductivities--the Allen Park clay is an order-of-magnitude lower.

A dissolved solids concentration equal to that of sea water was assumed in the leachate overlying the Allen Park clay. Sea water is a good "worst case" choice because sodium ions have high diffusion mobilities and are not preferentially adsorbed on clay exchange sites as heavy

TABLE 1. ALLEN PARK CLAY MINE

MONITOR WELL - WATER LEVEL READINGS

Well Number	Ground Elevation, Ft.	Well Elevation USGS [1]	Ground Water Elevation 11-4-81 [2]	Δ	Ground Water Elevation 5-29-81 [3]	Ground Water Elevation 3-26-81 [3]
2	595.1	600.76	600.67	5.6	600.44	600.21
5	595.7	605.92	605.09	9.4	604.62	604.49
7	594.1	597.35	591.01	-3.1	593.23	594.14
10	593.4	603.03	601.81	8.4	601.93	601.56
W-101	593.9	601.47	601.21	7.3		
W-102	591.3	600.81	603.22 [4]	11.9		
W-103	593.9	605.06	603.52	9.6		
W-104	594.1	603.82	603.81	9.6		
W-105	594.5	604.08	603.86	9.4		

$\Delta_{AV} = 8.9$

(1) Well Elevation is recorded as top of standpipe.

(2) Data Recorded by Michigan Testing Engineers, Inc.

(3) Data obtained from Michigan Department of Natural Resources.

(4) Well extended temporarily to obtain water level.

TABLE 2. COMPARISON OF AQUITARD PROPERTIES AND SITE PARAMETERS

AQUITARD PROPERTY OR SITE PARAMETER	OXNARD CALIFORNIA	ALLEN PARK MICHIGAN
Composition	clayey silt & silty clays	silty clay
Thickness, ft	30	25 - 35
Ave. Water Content, %	24	20
Ave. Liquid Limit, %	31	28
Ave. Hydraulic Conduct, cm/sec	1×10^{-7}	2.6×10^{-8}
Hydraulic Gradient	0.33 - 1.0 (downward)	2.7 (upward)
Initial (interstitial) Pore Water Solute Conc, ppm	1800	1550
Final Solute Conc, ppm	36,000	36,000 (assumed)
Chemico-Osmotic Coupling Coefficient, cm^5/mole/sec	6.2×10^{-4}	6.2×10^{-4}

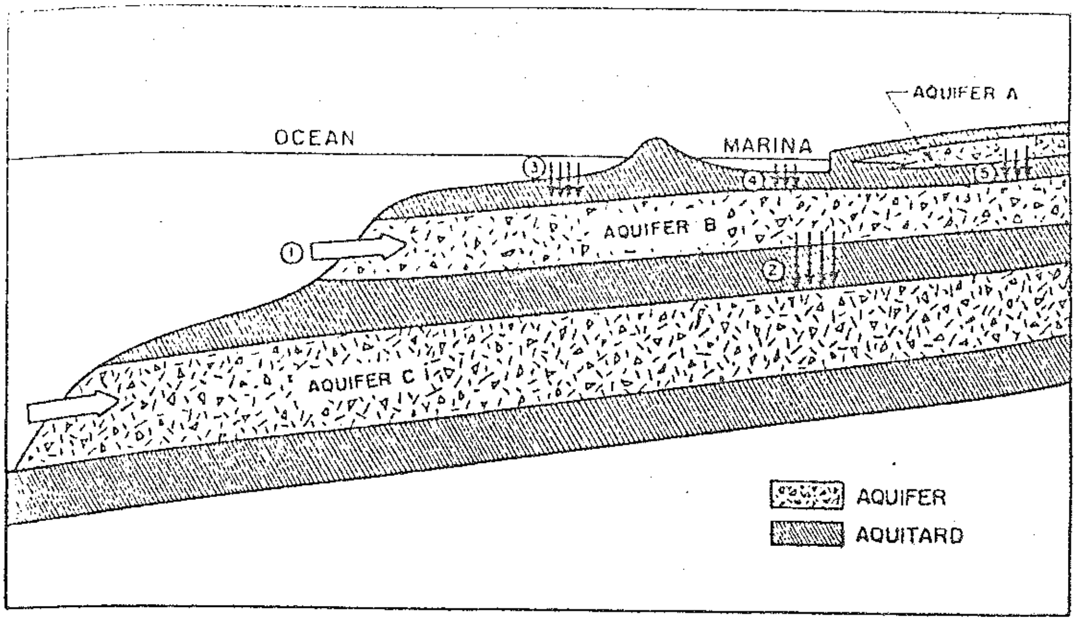


Figure 2. Generalized cross-section of multiple aquifer in a coastal basin. Salt flux across aquitard can occur as result of either salt water intrusion into aquifer (1,2) or salt water entering directly above aquitard in shallow coastal waters or marinas (3,4), or from salt contamination in near surface, perched aquifer (5).

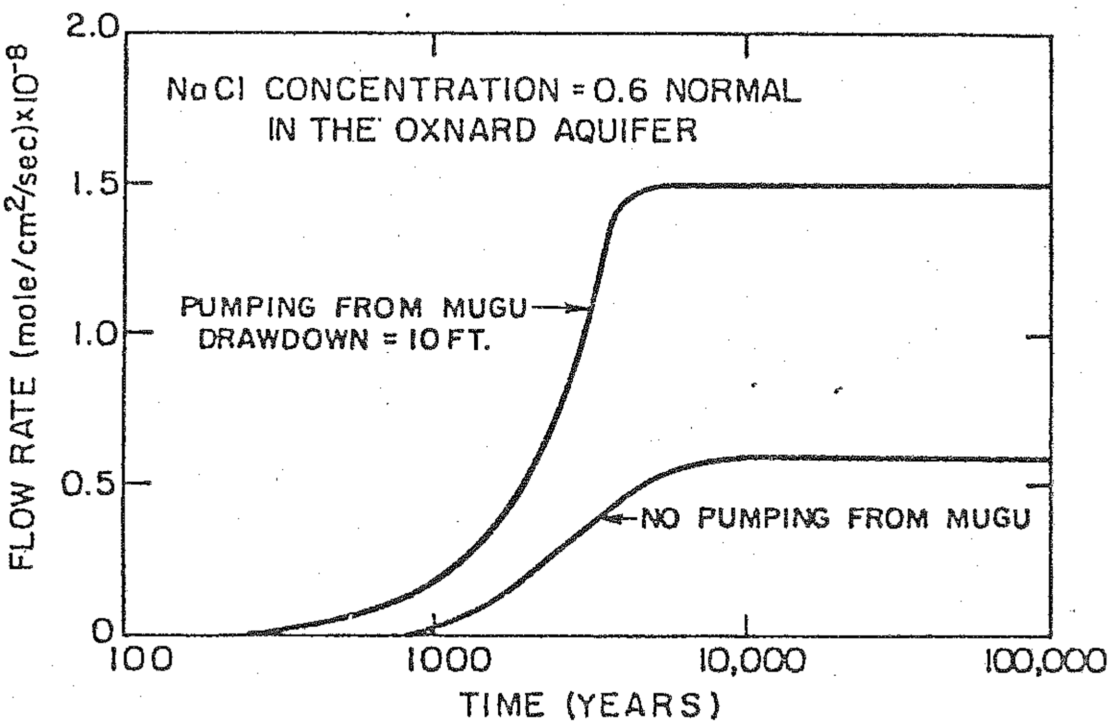


Figure 3. Solute efflux across aquitard into underlying aquifer as a result of salt water intrusion in overlying aquifer. Aquitard is 30 feet thick and has a hydraulic conductivity of 10^{-7} cm/sec. Pumping from lower (Mugu) aquifer superposes a 0.33 downward gradient on system.

metal ions would tend to be. The same chemico-osmotic coupling coefficient used in the California aquitard was also assumed applicable for the Allen Park clay. The value used is reasonable for the type of clay sediments present.

Results of the California study are presented in Figure 3 which shows the salt influx into the underlying aquifer as a function of time. Curves are presented for a no drawdown and 10-foot drawdown case (assuming the hydraulic gradient acts in the <u>same</u> direction as the salt concentration gradient). The horizontal portion of the two curves represents the steady state salt flux.

The main things to notice from this figure are the large breakthrough time (800 years) for the "no drawdown" case (i.e., in the absence of any hydraulic gradients) and the fact that in this aquitard the salt flux caused by drag coupling under a hydraulic gradient is larger. The steady state salt flux from the drag coupling under a combined 10-foot drawdown and salt concentration gradient is almost three times that from diffusion alone (no drawdown). Hence, in the event the hydraulic gradient was <u>reversed</u>, there would be no breakthrough and no downward salt flux provided the upward gradient exceeded about 0.2. In other words, under these conditions the two salt fluxes would be mutally opposed and exactly counterbalanced.

The relative contributions to steady state efflux in this example can be calculated with the aid of Equation 3. The following parameter values (taken from the study) were used in the calculation:

$$\partial h / \partial z \approx \Delta h / \Delta L = 10/30 = 0.33$$

$$\partial c / \partial z \approx (c_{s_2} - c_{s_1}) / \Delta L = \frac{0.57 \times 10}{914} = 0.62 \times 10 \text{ moles/cm}^4$$

$$c_s = (c_{s_2} + c_{s_1}) / 2 = \frac{(0.60 - 0.03) \times 10}{2} = 0.32 \times 10 \text{ moles/cm}^3$$

$$D = 10^{-5} \text{ cm}^2/\text{sec}$$

$$R = 8.32 \times 10^{7} \text{ ergs/mole/}^\circ\text{K}$$

$$T = 300\ ^\circ\text{K}$$

$$\gamma_w = 10^3 \text{ dynes/cc}$$

$$k_h = 10^{-7} \text{ cm/sec}$$

$$k_{ch} = 6.2 \times 10^{-4} \text{ cm}^5/\text{mole/sec}$$

Using these values the calculated contributions to steady state solute flux are respectively:

Drag Coupling: $J_{s_1} = [(\gamma_w/RT)c_s k_{ch} + c_s k_h]\, \partial h/\partial z$

$$= \left[\frac{10^3(2\times10^{-7})}{8.32\times10^7(.3\times10^{-3})} + 0.32\times10^{-3}(10^{-7})\right] 0.33$$

$$= 1.056 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{0.98 \times 10^{-8} \text{ moles/sec/ft}^2}$$

Chemico-Osmotic Diffusion:

$$J_{s_2} = [D + c_s k_{ch}]\, \partial c_s/\partial z$$

$$= [10^{-5} + 2\times10^{-7}]\; 0.62\times10^{-6}$$

$$= 0.63 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{0.58 \times 10^{-8} \text{ moles/sec/ft}^2}$$

The total salt flux is the sum of the contributions from drag coupling and chemico-osmotic diffusion or

$$J_s = J_{s_1} + J_{s_2}$$

$$= (0.98 + 0.58) \times10^{-8}$$

$$= \underline{1.56 \times 10^{-8} \text{ moles/sec/ft}^2}$$

These calculations are in agreement with the results shown in Figure 3 for steady state salt inflow under combined gradients. They also illustrate that the drag coupling contribution under a 10-foot drawdown (0.33 hydraulic gradient) exceeds the chemico-osmotic diffusion contribution.

In the case of the clay aquitard beneath the landfill at Allen Park, the average hydraulic conductivity is almost an order-of-magnitude lower (2.6×10^{-8} vs. 10^{-7} cm/sec). This will tend to decrease the drag coupling. On the other hand, this tendency will be more than offset by higher hydraulic gradients at this site. If the level of the leachate is kept at or close to the bottom of the landfill, then the gradient will approach 80/30 or 2.7. The drag coupling component of solute flux in this case will be

$$J_{s_1} = \left[\frac{10^3(2\times10^{-7})}{8.32\times10^7\,(.3\times10^{-3})} + 0.32\times10^{-3}\,(2.6\times10^{-8})\right] \times 2.7$$

$$= [\,0.008\times10^{-12} + 0.832\times10^{-11}\,] \times 2.7$$

$$= 2.25 \times 10^{-11} \text{ moles/sec/cm}^2$$

$$= \underline{2.09 \times 10^{-8} \text{ moles/sec/ft}}$$

This flux is greater than 3X the chemico-osmotic flux; and since it acts in the opposite direction, there will be no net downward flux of solute at the Allen Park site. The critical hydraulic gradient to maintain a zero net salt efflux is 0.8. This means that the groundwater table could rise to within 12 feet of present ground elevation (~595 ft) in the landfill and there would still be a sufficient upward hydraulic gradient (drag coupling effect) to completely counter solute efflux under chemico-osmotic diffusion (see summary below).

Position of Ground Water Table in the Landfill	Upward Hydraulic Gradient	Net, Steady State Solute Efflux Rate (moles/sec/ft^2)
At bottom	2.7	-1.51×10^{-8} (net influx)
12 feet from top	0.8	zero
At top	0.33	$+0.32 \times 10^{-8}$

These calculations are based on the existence of a static or piezometric head in the underlying aquifer approximately 9-10 feet above ground elevation (see Table 1).

Assumption of worst case conditions, namely, a rise in the groundwater table in the landfill to ground surface elevation, leads to a small, steady state efflux rate from chemico-osmotic diffusion. This occurs because the resulting hydraulic gradient (0.33) is no longer large enough to completely oppose the chemico-osmotic salt flux. The breakthrough times, however, would be so immense (1000's of years) that the steady state flux under these conditions is largely irrelevant.

It is important to note that the preceding calculations are also based on the following "worst case" assumptions:

1. A highly saline leachate with a concentration and composition equal to that of sea water.

2. No interaction between the solute and clay.

In actual practice, there would be some uptake and adsorption of solutes on the clay. This adsorption would attenuate or limit further solute concentrations in the leachate as it passed through the clay.

III. EFFECT OF LEACHATE CONSTITUENTS ON THE PERMEABILITY OF CLAY

A. GENERAL BACKGROUND

The possibility that leachate--either in the solvent or solute phase--might affect clay permeability and hence its containment integrity has been raised by a number of investigators (Anderson and Brown, 1981; Haxo, 1981; and Folkes, 1982). One of these studies has shown that concentrated organic liquids can increase clay permeability by several orders-of-magnitude (Anderson and Brown, 1981).

All of these studies were conducted in the laboratory with simulated leachates from particular types of wastes and under particular testing conditions. The danger of blindly applying these test results to a field situation have been noted recently by Gray and Stoll (1983). It is essential to ask the following before the results of these lab tests can be applied to a given field situation:

1. What was the nature of the leachate in the lab tests? What are the concentrations of various constituents in the leachate in the field as opposed to the lab tests? How relevant are the lab test results in the light of potentially large differences in leachate composition (lab vs. field)?

2. How did the leachate contact or interact with the clay in the lab tests? Was it forced through? If so, at what gradient? Is there any prospect that the leachate will be able to penetrate/permeate through the clay containment in the field in like manner? In other words are the necessary gradients and other conditions present to permit this to happen?

3. What was the failure or clay degradation process by which the apparent permeability increase occured in the lab tests? Was it by a) dissolution, b) syneresis, c) piping? Could these mechanisms reasonably occur in the field given the type, water content, and density of the in-situ clay plus the nature and concentration of organic and inorganic compounds in the leachate?

B. WASTE AND LEACHATE COMPOSITION AT THE ALLEN PARK CLAY MINE

The types, composition, and relative amounts of wastes placed in the Type II Solid Waste Landfill at Allen Park are shown in Tables 3 and 4. The results of typical E.P.T leachate tests on these wastes are shown in Table 5. The likely nature and composition of the landfill leachate can be estimated from this information. This estimate is adequate for purposes of evaluating the probable effect of the leachate on clay permeability.

TABLE 3. ALLEN PARK CLAY MINE - SOLID WASTE LANDFILL CONSTITUENTS

Fly Ash	-	50%
Blast Furnace Filter Cake	-	15%
Construction Debris - Sweepings - Clean-Up	-	14%
BOF Dust	-	6%
Foundry Sand	-	6%
Electric Furnace Dust	-	4.8%
Coal and Coke	-	3%
Coke Oven Decanter Tar Sludge	-	0.6%
Glass	-	0.5%
Wood Ash	-	0.5%
BOF Kish	-	0.3%
Wastewater Treatment Sludge	-	0.2%
Grinding Mud	-	0.1%

TABLE 4. ALLEN PARK CLAY MINE WASTES. TYPICAL AS RECEIVED ANALYSES (mg/kgm).

	Decanter Tank Tar Sludge	Electric Arc Furn. Dust	Blast Furn. Flue Dust	BOF Flue Dust	Blast Furn. Filter Cake	Foundry Sand	BOF Kish	Fly Ash	Lime Dust	[illegible]
EP Toxic	No	Yes(Zn,Pb,Cd)	No	No	No	No	No	Exempt	No	
Iron	----	350,000	122,000	560,000	150,000	1,200	490,000	34,500	----	[illegible],800
Carbon	----	4,700	520,000	7,400	404,000	6,600	240,000	194,000	----	[illegible]0,000
Arsenic	----	50	19	42	2	20	78	----	----	15
Barium	----	<1	<1	<1	20	<1	<1	----	----	<1
Cadmium	----	95	<1	50	8	<1	<1	----	----	<1
Chromium	----	500	<1	130	70	<1	60	----	----	1
Lead	----	<4,500	<1	3,000	350	44	<1	----	----	[illegible]
Mercury	----	<1	<1	<1	<1	<1	<1	----	----	<1
Selenium	----	120	98	<1	<1	35	70	----	----	[illegible]
Silver	----	6	<1	<1	9	<1	<1	----	----	15
Manganese	----	39,000	7,500	10,000	4,500	79	2,800	----	----	70
Zinc	----	150,000	120	22,000	400	40	194	----	----	110
Phosphorus	----	450	200	190	300	400	170	----	----	90
Sulfur	----	3,600	4,000	1,600	4,000	200	850	3,100	----	7,300
Calcium	----	61,000	18,000	2,000	20,000	60	580	13,100	714,700	300
Magnesium	----	11,000	7,500	9,600	13,000	100	3,800	5,400	----	300
Aluminum	----	2,400	2,200	<2	3,700	<2	1,600	147,200	----	<2
Silicon	----	15,000	28,000	8,000	83,000	450,000	25,000	201,700	----	20,000
Potassium	----	5,900	980	5,000	2,200	170	640	9,700	----	220
Sodium	----	5,200	440	2,300	1,500	390	630	3,700	----	690
Fluorine	----	26	10	23	4	<1	48	----	----	<1
Cyanide	14	<1	<1	<1	3	<1	<1	----	----	2
Phenol	1,800	<1	<1	<1	3	<1	2	----	----	3
Naphthalene	2,700	----	----	----	----	----	----	----	----	----

TABLE 5. ALLEN PARK CLAY MINE SOLID WASTES
TYPICAL E.P.T. LEACHATE TEST RESULTS (Mg/l)

Parameter	Blast Furnace Flue Dust	BOF Flue Dust	Blast Furnace Filter Cake	Foundry Sand	BOF Kish	Coke Breeze	Wastewater Treatment Sludge
Arsenic	0.04	0.02	< 0.1	0.03	0.1	< 0.1	.00[illegible]
Barium	< 0.8	< 0.04	< 0.8	< 0.08	< 0.8	< 0.8	.45
Cadmium	0.01	0.03	< 0.08	< 0.005	< 0.005	< 0.005	.005
Chromium	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	.101
Lead	< 0.2	1.7	1.7	< 0.2	< 0.2	< 0.2	.005
Mercury	0.0007	< 0.01	< 0.2	< 0.2	< 0.2	< 0.2	.0005
Selenium	1.0	< 0.01	< 0.[illegible]	0.10	0.4	< 0.5	.00[illegible]
Silver	< 0.1	< 0.01	< 0.01	< 0.1	< 0.1	< 0.1	.00[illegible]

Compiled By [illegible]
March 1, 19[illegible]

The data in Tables 3 and 4 indicate that 50 per cent of the solid waste consists of relatively inert fly ash and that some 89 per cent of the wastes consist of materials that do not contain significant amounts of heavy metals (Zn, Pb, Cd) or organics known or suspected to be toxic such phenol and naphthalene (see Table 4). The coke oven decanter tar sludge is a possible source of organics (phenol and napthalene), but this waste comprises only 0.6 per cent of the total stream in the Type II Solid Waste landfill.

C. PROBABILITY OF ORGANICS IN LEACHATE AFFECTING CLAY PERMEABILITY AT ALLEN PARK SITE

Anderson and Brown (1981) found that several organic liquids, viz., aniline, acetone, ethylene glycol, heptane, and xylene, cause large increases in permeability of four compacted clay soils. Pure organic liquids were used in their study. One of the authors (Anderson, 1982) later emphasized that their results cannot be used to support claims that clay liners permeated by dilute organic liquids may be susceptible to large permeability increases.

Haxo (1981) reported results of up to 52 months of liner exposure to selected industrial wastes. He included several organic wastes, namely, aromatic oil, Oil pond 104, and a pesticide. The results of large permeameter tests on a compacted fine-grained soil and admixed materials are summarized in Table 6. Although a small amount of seepage passed through the compacted, fine-grained soil liner, no permeability increases were reported with any of the organic wastes.

On the basis of these studies and with the caveats noted at the beginning of this section in mind, it is possible to evaluate the likely effect of the landfill leachate on clay permeability at the Allen Park site.

1. Type II Solid Waste Landfill

As noted previously the existing landfill contains small quantities of coke oven decanter tar sludge which is a possible source of organics (phenol and naphthalene), but this waste comprises only 0.6 per cent of the total. Phenol and naphthalene are present in the tar component of this waste in concentrations estimated by Desha (1946) of 0.1 and 2.2 per cent by weight respectively. Accordingly, the amount of phenol and naphthalene present in the total waste stream are .006 and .013 per cent by weight respectively. These amounts constitute a very low fraction and they suggest that leachate from the total waste stream will tend to have very low concentrations of phenol and napthalene. Therefore, the organics in the leachate from the Type II Solid Waste landfill are quite unlikely to affect clay permeability.

TABLE 6. EFFECTS OF INDUSTRIAL WASTES ON SOIL AND ADMIX LINERS (from Haxo, 1981)

Liner material	Acidic waste (HNO_3, HF, HOAC)	Alkaline waste (spent caustic)	Lead (low lead gas washing)	Oily waste: Aromatic oil	Oily waste: Oil pond 104	Pesticide (weed killer)
Compacted fine-grained soil 305 mm thick	Not tested	Measurable rate of seepage $v_s = 10^{-10}-10^{-9}$ m/s, waste penetrated 3–5 cm after 30 months (*a*)		$k=1.8\times10^{-10}$ $k=2.4\times10^{-10}$ $k=2.6\times10^{-10}$ (tests on soil after 30 months)	†	†
Soil cement 100 mm thick	Not tested	No measurable seepage after 30 months				
Modified bentonite and sand (2 types) 127 mm thick	Not tested	Measurable seepage after 30 months, channelling of waste into bentonite (*b*)			Failed (waste seepage through liner)	‡
Hydraulic asphalt concrete 64 mm thick	Failed	Satisfactory	Waste stains below liner asphalt mushy	Not tested	Not tested	Satisfactory
Spray-on asphalt and fabric 8 mm thick	Not tested	Satisfactory	Waste stains below liner	Not tested	Not tested	Satisfactory

*From data presented by Haxo (1981).
†Same as (*a*).
‡Same as (*b*).

2. Type I Hazardous Waste Landfill

In the future the decanter tar sludge will be placed in a separate landfill that will be upgraded to accept hazardous wastes. This action will increase the relative proportion of organics (phenol and naphthalene) in the waste stream. Leachate tests run on pure samples of decanter tar sludge using a distilled water extraction procedure (Calspan, 1977) have produced phenol concentrations of approximately 500 ppm. Even this concentration is far removed from the very high concentrations of organic solvents used by Anderson and Brown (1981) in their permeability tests on different clays. Accordingly, organics in the leachate from the Type I Hazardous Waste landfill are also unlikely to affect clay permeability.

In summary: It does not appear likely nor reasonable that organics present in the wastes at the Allen Park Clay Mine/Landfill will cause a permeability increase given their low concentration and the absence of any substantiation in the published technical literature for such an increase under these conditions.

IV. CONCLUSIONS

(1). There appears to be very little likelihood of leachate migrating downward from the Allen Park Clay Mine/Landfill and contaminating the aquifer beneath the clay.

(2). A density difference between the leachate and groundwater will have little or no influence on hydraulic permeability or downward migration nor will it lead to diffusion efflux of solutes. A thick, uniform bed of silty clay beneath the site coupled with an upward hydraulic gradient precludes the latter. Calculations and analyses are provided herein to support this finding.

(3). Comparison with results of salt water intrusion studies across clay aquitards having similar properties as the clay beneath the Allen Park Clay Mine site show that the solute (salt) will take at least 800 years to migrate across a clay barrier 30 feet thick under chemico-osmotic gradients alone. A counter (or upward) hydraulic gradient will increase this breakthrough time even more.

(4). The waste and its leachate are unlikely to increase the permeability of the underlying clay. This claim is reasonable in view of the low concentrations of organics in the total waste stream and in the light of the findings and caveats of permeability/exposure tests with organic permeants reported in the technical literature. This conclusion applies to both the existing Type II Solid Waste landfill and a proposed Type I Hazardous Waste landfill that will accept the coke oven decanter tar sludge.

(5). The composition of the waste and underlying clay do not suggest properties or combination of properties that could lead to a containment failure caused by such processes as piping, acid/base dissolution, or syneresis.

(6). Under these circumstances any observed increase in contaminant levels of monitor wells in the aquifer underlying the site could just as well come from other sources laterally upgradient from the site rather than from the clay mine/landfill above the site.

(7). These findings and conclusions support the basis of applicant's petition for discontinuing further monitoring of the wells penetrating the aquifer beneath the site.

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